ATO Technology Development

Performance Metrics Results to Date

April 2005

This is the fifth semi-annual report on Air Traffic Organization (ATO) Technology Development performance metrics. The intent is to describe performance metrics analyses and results performed from November 2004 through April 2005. This edition contains summaries of previous work and presents some new analyses. The new studies include:

An updated examination of flight time/distance for Automatic Dependent Surveillance-Broadcast (ADS-B) equipped United Parcel Service, Inc. (UPS) aircraft at Louisville International Airport (SDF),

An updated chart of ADS-B usage along the East Coast corridor and survey results concerning ADS-B usage at Embry-Riddle Aeronautical University (ERAU),

A description of the Runway Status Lights (RWSL) test at Dallas/Fort Worth International Airport (DFW),

A historical study of the effectiveness of Runway Guard Lighting (RGL) at several airports and survey results for a new RGL system at North Las Vegas Airport (VGT),

And an updated analysis of departure capacity at Memphis International Airport (MEM) after implementation of surface surveillance data to airline ramp controllers at Federal Express (FedEx).

EXECUTIVE SUMMARY

This is the fifth semi-annual report on Air Traffic Organization (ATO) Technology Development performance metrics. It presents performance metrics analyses and results performed from November 2004 through April 2005.

There are numerous performance metrics activities within the three ATO Technology Development product teams (Future Surveillance, Surface Systems, and Data and Communications) that include research analysts from the following organizations: the FAA, American Airlines, Calibre Systems, Inc., The CNA Corp. (CNAC), Dallas/Fort Worth International Airport, Delta Air Lines, Federal Express (FedEx), Global Engineering Management Services, Inc. (GEMS), Johns Hopkins Applied Physics Lab, MCR Federal, LLC, MITRE CAASD, Northwest Airlines, Optimus Corp., Sensis Corp., United Parcel Service Inc. (UPS), Veracity Engineering, and the Volpe National Transportation Systems Center. The purpose of the combined metrics effort is to consolidate the ongoing metrics activities and perform new analyses where needed. This report compiles the various efforts performed during the last six months into one document for ease of use. Results from these analyses will be incorporated as part of future program cost-benefit and investment analyses.

This document is divided into separate sub-sections for each site where there is an active metrics effort.

SDF: The Future Surveillance Terminal and Surface Application Groups continue to develop a test-bed for early implementation of NAS equipment at Louisville International Airport (SDF). Currently, Future Surveillance is exploring the benefits of using Automatic Dependent Surveillance-Broadcast (ADS-B) equipment and procedures in the terminal area, and shared multilateration surveillance data on the surface. An ADS-B environment allows equipped aircraft to see surrounding aircraft on a Cockpit Display of Traffic Information (CDTI). Surface multilateration allows real-time surveillance for use by airline ramp control and management. We began a metrics working group at SDF in August 2003. In this document, we update previous flight time and distance analyses from *Performance Metrics Results to Date October 2004* [1].

The updated analysis examines distances and times for all UPS arrivals at SDF, UPS arrivals during a high equipage peak, and non-UPS arrivals as a control group. We compare track data from the first year of full CDTI equipage to two year-long baseline data sets. The first baseline set excludes data during the equipage ramp-up period; the second set includes this transition period data. We divided data into different weather conditions (Visual Approach, VA, conditions and Instrument Approach, IA, conditions) and airport configurations (North Flow and South Flow). We list the results for the baseline set that excluded transition period data in the following table. Positive values signify decreases in flight distance or time in the post-implementation period. A decrease in time or distance represents an increase in efficiency. **Not Sig** identifies a difference in means that was not statistically significant at the 95% level**.** UPS flights showed significant distance savings during North Flow operations. The savings tend to be larger for aircraft that arrive during the high CDTI equipage peak.

Using Baseline Data Set 1	Metric	Non-UPS flights	All UPS flights	B757/767 peak UPS flights
VA North	**Dist Savings**	1.7 nmi	3.3 nmi	3.7 nmi
	Time Savings	31 sec	44 sec	31 sec
	% flights in config	29%	50%	59%
IA North	**Dist Savings**	0.8 nmi	4.7 nmi	6.0 nmi
	Time Savings	Not Sig	77 sec	74 sec
	% flights in config	9%	12%	13%
VA South	**Dist Savings**	1.4 nmi	0.5 nmi	1.7 nmi
	Time Savings	22 sec	Not Sig	Not Sig
	% flights in config	53%	32%	23%
IA South	**Dist Savings**	Not Sig	Not Sig	Not Sig
	Time Savings	Not Sig	Not Sig	Not Sig
	% flights in config	9%	6%	5%

East Coast and Embry-Riddle Aeronautical University (ERAU): The Future Surveillance Flight Safety Application Group has been instrumental in stimulating production and self-equipage of ADS-B for the general aviation (GA) community. They have begun to provide free traffic and weather information from several ADS-B ground stations along the East Coast. They also support ADS-B implementation at ERAU in Prescott, Arizona and Daytona Beach, Florida. Both ERAU sites became operational in the summer of 2004. In this document we update the current total ADS-B equipage (GA and carrier) as detected from available ground stations, and present survey results from ERAU at Prescott.

DFW RWSL: The Surface Systems Team supports the mission of the FAA's Runway Incursion Reduction Program (RIRP) by exploring, evaluating, and validating current and emerging technologies that show potential for increasing runway safety in the NAS. The Runway Status Lights (RWSL) program is a fully automatic advisory safety system designed to reduce the number and severity of runway incursions using fused surface surveillance data. Evaluation of RWSL is ongoing at Dallas-Fort Worth International Airport (DFW). In this document, we describe the current activities and summarize past projections of the effectiveness of RWSL from a past study of runway incursions.

DFW data sharing: A major enabler of the RWSL project at DFW is the installation of an Airport Surface Detection Equipment - Model X (ASDE-X) multilateration system. In March 2002, the FAA agreed to provide real-time multilateration surface data to American Airlines, Delta Air Lines, and the DFW Airport Board. The shared surface surveillance feed became stable enough for consistent use in November 2003. The metrics team began a metrics working group in December 2003. In this document, we summarize previous analyses from *Performance Metrics Results to Date October 2004* [1].

North Las Vegas (VGT): The Surface Systems Team is also testing the effectiveness of enhanced additional Runway Guard Lighting (RGL) as a runway incursion prevention tool to be used uniformly on the airport surface during all weather conditions. These lights assist pilots in identifying the runway hold position, usually identified by surface markings or runway hold signs. In this document we present recent survey results and a study of the effect of RGL on the runway incursion rate at other airports.

MEM: The Future Surveillance Surface Applications Group assisted Federal Express (FedEx) and Northwest Airlines (NWA) in obtaining data for surface surveillance systems for use by ramp controllers and others within these airlines to whom this information is useful. The shared data is part of the prototype Surface Management System (SMS). In *Performance Metrics Results to Date April 2004* [2], we used an unexpected loss of surveillance to gauge the operational impact of surface data to FedEx. In *Performance Metrics Results to Date October 2004* [1], we updated the taxi-out analysis to examine queue lengths and departure rates. In this document we summarize the previous results, and present a new analysis that examines the maximum departure rate, or departure capacity, for different runway configurations and weather conditions at the airport. We find an increase in departure capacity between 5 and 10 aircraft an hour when the airport is operating in North Flow.

DTW: Technology Development assisted Northwest Airlines (NWA) in obtaining surface surveillance data from a prototype multilateration system, the Airport Target Identification System (ATIDS) at Detroit Wayne County Metropolitan Airport (DTW). NWA uses this data on a daily basis as the primary display for each controller in the ramp control tower, and has several displays for analysts, managers, and dispatchers at the Systems Operations Center (SOC) in Minneapolis. In *Performance Metrics Results to Date October 2003* [3], we described the benefit mechanisms and presented estimations of the benefits in detail. In *Performance Metrics Results to Date October 2004* [1], we presented a new description of how ATIDS helped NWA permanently transform deicing operations. The new description included a list of long-term changes. In this document we summarize the previous results.

Gulf of Mexico (GOM): In March of 2003, the Future Surveillance En route and Oceanic Group began a concerted effort to identify benefits for ADS-B, improved communications, and automated weather observations in the Gulf of Mexico. The metrics team assisted in the benefits identification process, gathered baseline data, and analyzed this data. In *Performance Metrics Results to Date April 2004* [2], we presented the current benefits analyses. In this document we summarize the previous results.

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1.0 INTRODUCTION

This is the fifth semi-annual report on ATO Technology Development performance metrics. The intent is to describe performance metrics analyses and results performed from October 2004 through April 2005.

The metrics effort consolidates ongoing metrics activities and performs new analyses where needed. The goal of this effort is to provide information for management oversight and communication with stakeholders by gauging the current operational impact and user benefits of Technology Development initiatives.

There are numerous performance metrics activities within the three product teams of Technology Development (Future Surveillance, Surface Systems, and Data and Communications) that include research analysts from the following organizations: the FAA, American Airlines, Calibre Systems, Inc., The CNA Corp. (CNAC), Dallas/Fort Worth International Airport, Delta Air Lines, Federal Express (FedEx), Global Engineering Management Services, Inc. (GEMS), Johns Hopkins Applied Physics Lab, MCR Federal, LLC, MITRE CAASD, Northwest Airlines, Optimus Corp., Sensis Corp., Trios Associates, Inc., United Parcel Service Inc. (UPS), Veracity Engineering, and the Volpe National Transportation Systems Center. This report compiles the various efforts performed during the last six months into one document for ease of use. Results from these analyses will be incorporated as part of future program cost-benefit and investment analyses.

Performance metrics are quantitative measures of operational impacts. They are measures of changes in activity, including but not limited to: runway incursion rates, actual arrival and departure rates, flying time and distance for flight segments, and taxi times. The benefit of these activity changes may only apply during specific demand loads or during certain weather conditions. We will adjust the metrics as needed to best reflect the capabilities of the applications and initiatives.

The metrics reflect the FAA's operational goals and the expected program operational impacts. As we gain more experience with the program capabilities, the performance metrics will evolve. The metrics will remain flexible, and they will be refined as a direct result of feedback from FAA staff and users. We expect to incorporate additional metrics into future documents, especially after the implementation of new tools or initiatives.

Note that performance metrics can differ from programmatic metrics. Programmatic metrics assess whether a program or tool attains its intended function: the cost, maturity, risk, and functionality of the capability itself. An example of a programmatic metric might be the effective range of an ADS-B transmitter. These programmatic metrics are important for the operational impact evaluation, as they demonstrate the cause of an observed change in NAS performance. The metrics team will work closely with the individual Technology Development Product Teams to associate tool performance with operational impacts.

Cost/benefit analyses attempt to translate the impacts of applications into economic benefits. These analyses are necessary for continued use and increased implementation of such applications. The cost/benefit team concentrates on estimating future benefits for sites before implementation. The metrics effort focuses on current benefits, but will use estimates from prior cost/benefit analyses and, in turn, provide refined estimates for use in future benefits studies.

1.1 Relation to other documents

The first step in the metrics process involved consolidating the separate metrics efforts into a combined effort. Much of the metrics/benefits work involves the Future Surveillance Team, formerly the Safe Flight 21 (SF-21) Team. Consequently, this report borrows heavily from the Safe Flight 21 Master Plan Version 3 [4] and a previous cost/benefit analysis from the SF-21 Cost/Benefit Analysis group [5].

The Safe Flight 21 Master Plan [4] outlines nine major enhancements. These are:

Weather and Other Information In The Cockpit

Cost-Effective Controlled-Flight-Into-Terrain (CFIT) Avoidance

Improved Terminal Operations in Low Visibility

Enhanced See and Avoid

Enhanced En Route Air-to-Air Operations

Improved Surface Surveillance and Navigation for the Pilot

Enhanced Surface Surveillance for the Controller

ADS-B Surveillance in Non-Radar Airspace

ADS-B Surveillance in Radar Airspace

The nine enhancements involve several applications grouped into four classifications for effective management: Surface Applications, Terminal Applications, En route and Oceanic Applications, and Flight Safety Applications. In this report, we will establish a link to the nine enhancements where appropriate. We will also measure the impact of additional enhancements beyond the initial nine listed in the Master Plan.

It is hoped the enhancements provided by the Future Surveillance applications will positively impact the system by producing safety and efficiency user benefits. Prior cost/benefit work describes such potential benefits and estimates the effectiveness of these applications.

Table 1-1 from The Safe Flight 21 Pre-Investment Analysis Cost/Benefit Analysis (CBA) Phase II Report [5] lists both safety and efficiency benefits for which economic benefits were estimated. Note that some of the impacts rely on the interdependency of more than one enhancement.

Table 1-1. Safety and Efficiency Benefits Quantified

Safety Benefits	Efficiency Benefits
Enh1: Weather Accident Reduction Benefits	Enh1: More Efficient Routes in Adverse Weather*
Enh1: NOTAMs Related Accident Reduction Benefits*	Enh3: Reduction in MVMC Arrival Delays*
Enh2: CFIT Accident Reduction Benefits	Enh6: Reduction in Taxi Times Due to Pilots Enhanced Situational Awareness
Enh4: Mid-Air Collision Accident Reduction Benefits	Enh8: Reduction in SVFR Delays*
Enh8: More Timely Search and Rescue Benefits*	Enh8: More Efficient Search and Rescue Benefits*
Enh6&7: Surface Accident Reduction Benefits	Enh3&7: Reduction in Arrival and Departure Delays

* Benefits not previously quantified in the Phase I analysis

The Phase II CBA report provides comprehensive lists of benefits for each enhancement beyond those quantified in Table 1-1. The benefits include qualitative and quantitative measures for both safety and efficiency.

In this report, we define appropriate metrics to demonstrate the benefits, choosing to focus on benefits that can be measured with available resources. As mentioned in the previous section, we will organize the metrics by site. However, we will refer back to the nine enhancements when possible in order to aid future benefits analyses. The CBA group will extrapolate the results of these metrics to support continued use and wider implementation of the Future Surveillance applications.

1.2 Organization

The remainder of this document is divided into separate sections for each Technology Development site where there is an active metrics effort.

Section 2 – Louisville International Airport, Standiford Field (SDF)

Section 3 - East Coast and Embry-Riddle Aeronautical University (ERAU)

Section 4 – Dallas Fort Worth International Airport (DFW), Runway Status Lights (RWSL) project

Section 5 – DFW, Data Sharing Activities

Section 6 – North Las Vegas Airport (VGT)

Section 7 – Memphis International Airport (MEM)

Section 8 – Detroit Wayne County Metropolitan Airport (DTW)

Section 9 – Gulf of Mexico (GOM)

Each section contains subsections that review the system description and history at that site, explain the metrics activities, and present results.

1.3 What is a benefits flow?

In the introduction, we defined performance metrics as measures of changes in activity. While measuring a change in a particular metric is simple, interpreting the results is sometimes difficult. The most complex part of benefits analysis is attributing a change to the use of an application. We attempt to better understand the activity changes by outlining the mechanisms for benefit in a specific format, which we call a "benefits flow."

The benefits flow process begins with a meeting of all the users of the new application. Operators explain the direct impact of each application-driven capability and discuss the changes in airport operations that arise from these impacts. Subsequently, we develop concise descriptions of each operational change. The benefits flow is a diagram that serves as an outline for this narrative framework. It has four columns: *capabilities*, *direct impacts*, *outcomes*, and *benefits*. For clarity, we define these words below for our context:

Capability – what the new application provides the users

Direct Impact – how the new or improved capability enhances user operations

Outcome – the result of the direct impacts on airport/airline operations

Benefit – how the outcomes improve airport/airline operations in terms of quantifiable measures

There are a number of these benefits flow diagrams in this document. The paragraphs following each diagram describe the flow in a narrative format that includes a problem statement, describes how the application helps to solve the problem, and summarizes any evidence so far collected. The narratives are organized by outcome. If the descriptions were given in an earlier document and there is no further evidence or information at this time, we simply present the diagram without the detailed descriptions and reference the document with the detailed descriptions.

The outlines and accompanying descriptions provide a focus for the analyses presented.

2.0 SDF

2.1 System Description and History

Over the past few years, Future Surveillance has partnered with United Parcel Service (UPS), local Air Traffic Control (ATC), and the Regional Airport Authority to test early implementations of NAS equipment at Louisville International Airport (SDF)[6,7]. Currently, Future Surveillance is exploring the benefits of using Automatic Dependent Surveillance-Broadcast (ADS-B) equipment and procedures in the terminal area, and shared multilateration surveillance data on the surface. An ADS-B environment allows equipped aircraft to see surrounding aircraft on a Cockpit Display of Traffic Information (CDTI). Surface multilateration allows real-time surveillance for use by UPS ramp control and management.

2.1.1 Airport Description and UPS Operations

This section briefly describes the operational test-bed at SDF and considers some details of the UPS freight operation.

SDF is the major worldwide hub for UPS. Figure 2-1 displays a diagram of the airport surface with buildings and runways in black and taxiways and parking areas in gray. The UPS sorting facility dominates the land area between the runways. While local ATC controls all traffic on taxiways and runways, UPS controls ground traffic in the large ramp and parking areas around their facilities.

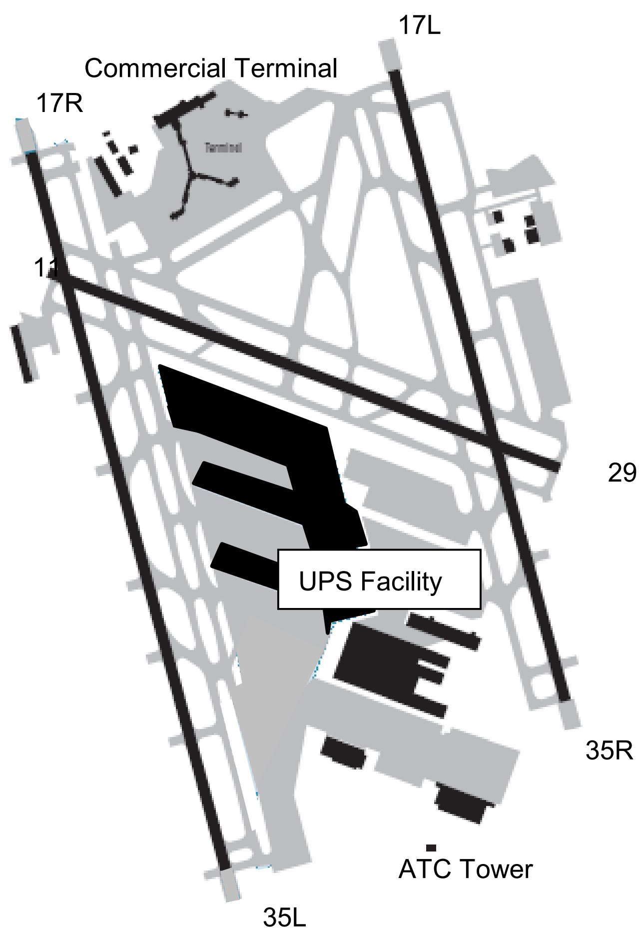


Figure 2-1. SDF surface layout

On weekdays during daylight hours, operations are divided about equally between commercial air carrier traffic and UPS two-day package air service. At night (after 11:00 pm local time), nearly all traffic into SDF is UPS overnight air service traffic. It is at night during the UPS arrival and departure pushes that SDF reaches its highest arrival and departure rates.

Because of the many connections necessary and the overnight time constraint, UPS must operate as peaked a schedule as possible to increase efficiency. On a typical operating night, well over 100 aircraft arrive between 11:00 pm and 2:30 am local time. The overnight packages are sorted and leave on departing flights between 4 am and 6 am. Inefficiencies in air or ground operations can lead to sort delays that can subsequently delay all outgoing flights. Increased efficiency (decreased flight or taxi time) can allow more sort time or later departure from satellite airports.

Our focus is measuring the impact of ADS-B/CDTI in the terminal area and multilateration surface surveillance data sharing. Since these systems must interact with current and future FAA and UPS equipment, Future Surveillance is also interested in the continuing development of related systems (i.e. ARTS IIIE, ASDE-X) and operational tests. Below we list the important changes in the system since January 2003:

- 2/2003 - Stabilized approach requirement for visual approaches into SDF changed from 500 ft. To 1000 ft.
- 4/2003 through 6/2004 - UPS installed ADS-B in 107 aircraft (75 out of 75 B757s and 32 out of 32 B767s)
- 8/2003 - SDF TRACON switched to ARTS III-E from ARTS III-A
- 10/2003 – Surface Management System (SMA) installed at UPS
- 4/2004 – UPS changes to the LIDO flight plan software
- 5/2004 – the ILS for runway 35R was inoperable for most of May 2004
- 9/14/2004 – 9/25/2004 – Constant Descent Approach (CDA) test affecting flight pattern for last several arrivals during night rush
- 12/8/2004 – new arrival procedure for last 16 arrivals during night rush.

We will attempt to take these changes into account when analyzing the data to check for potential effects.

2.1.2 ADS-B/CDTI Description

ADS-B aircraft applications make use of the extremely accurate position and velocity information available now with ubiquitous Global Positioning Satellite (GPS) coverage. ADS-B aircraft automatically broadcast information once per second. Besides known GPS position, the ADS-B messages contain call sign, heading, altitude, speed, and aircraft category. Other properly equipped ADS-B aircraft and ground stations can receive these messages. The ground stations can provide controllers with additional surveillance from these ADS-B aircraft.

The CDTI is a flight deck display that presents relative position of other traffic in the vicinity with respect to one's own aircraft using the ADS-B information. Equipped UPS aircraft receive CDTI on a multifunctional display that can also show weather and other traffic information broadcast from the ADS-B ground stations. Figure 2-2 shows a detail of the multi-functional display and gives an example of cockpit position.

Figure 2-2. Left-cockpit location of CDTI, Right-CDTI detail

Figure 2-3 details some of the traffic features available on the UPS CDTI. Specifically it focuses on information available on a user-selected aircraft. This information includes range, climb/descent rate, closure rate, and call sign, as indicated in the figure. This information is useful to pilots during airport approaches.

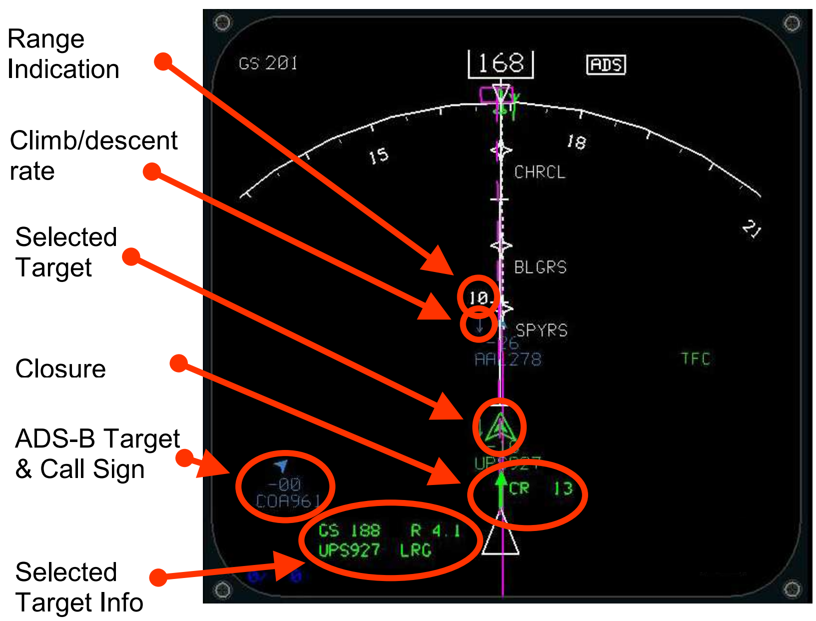


Figure 2-3. Detail of CDTI screen showing some traffic features

UPS began equipping aircraft with CDTI systems in April of 2003. They have concentrated on B-757s and B-767s because these represent the majority of the fleet (65 percent). The UPS domestic fleet consists of 75 B-757s and 32 B-767s.

Figure 2-4 shows the number of operating CDTI equipped aircraft during the installation period from March 2003 through March 2004. The top line is the total number of aircraft and the lower two are the separate counts of B757s and B767s. The dotted line that starts in June 2003 is the number of ADS-B aircraft recognized by the Comprehensive Real-time Analysis of Broadcast Systems (CRABS) tool. Johns Hopkins Applied Physics Laboratory (JHUAPL) developed the CRABS tool to record and display track information from ADS-B sensors. UPS Airbus aircraft or other non-UPS ADS-B aircraft may explain the difference between total and observed. The lines dip in November because the B767s had to undergo a system modification. The B767s came back online in late January 2004. UPS completed equipping their B757/B767 fleet (107 aircraft) in the spring of 2004.

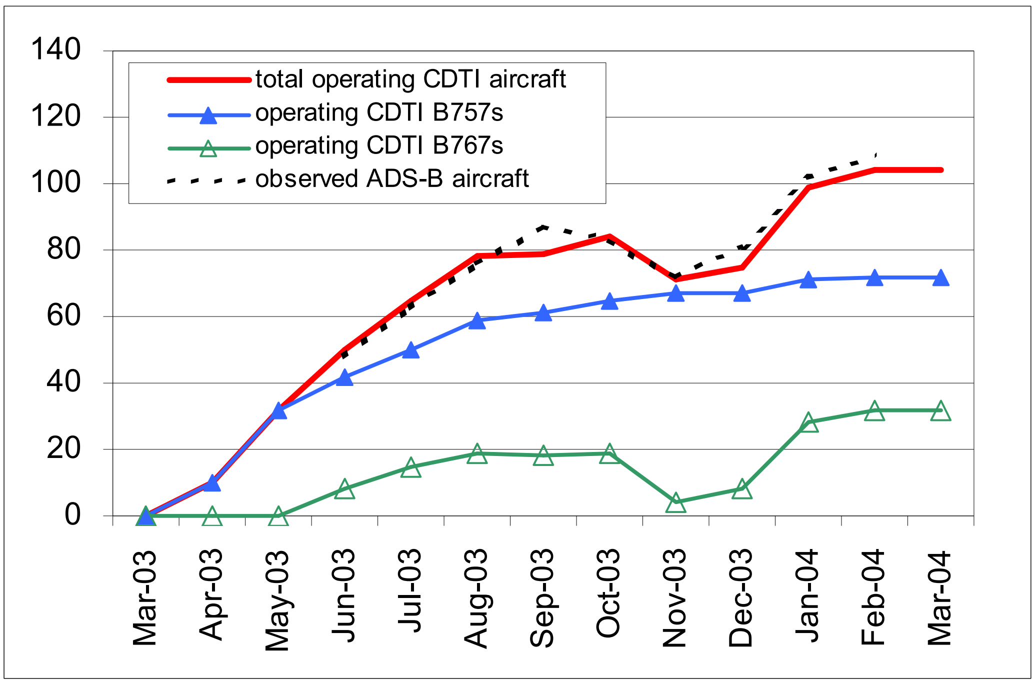


Figure 2-4. Monthly operating CDTI units from March 2003 – March 2004

2.1.3 Surface Surveillance Description

UPS has also installed displays for surveillance and identification of all transponder-equipped (not just ADS-B equipped) aircraft on the surface. The FAA Airport Detection Equipment, Model-X (ASDE-X) system and the Surface Management System (SMS) provide the data. The ASDE-X system became operational in the SDF FAA tower on April 1, 2005. A version of the SMS, using ASDE-X data, is currently being integrated with the current UPS ramp software. ASDE-X employs position data from ten ground-based receivers using multilateration. Call signs are acquired through a link to current FAA ATC terminal automation tools. UPS first used the system in their ramp control area for slower daytime surface operations in August 2004, and will begin to use surface surveillance for the night operations after integration of the SMS and UPS software.

2.2 Metrics Activities

Future Surveillance established a metrics working group at SDF in June 2003 to collect metrics data and other pertinent information to evaluate efficiency and safety. The group currently includes members from the FAA, NATCA, SDF ATC, the SDF Regional Airport Authority (RAA), and UPS.

In September 2003, the working group discussed the current operational impact of both data sharing on the surface and enhanced situational awareness/see and avoid in the terminal area. Members explained the direct impact of each capability and discussed the benefits that arise from these impacts. Subsequently, we developed "benefits flows" that outline the impacts and provide concise narrative descriptions of each benefit.

Currently, the group continues collecting data and performing analyses to gauge the described benefits. The current data collection effort archives flight tracks in the air and on the surface, ATC and UPS radio frequency loads, UPS logs on surface crew times, and a large variety of operational and human factors measures.

2.3 Results

We developed separate benefits flows for the surface and the terminal area. For an explanation of the benefits flow process see section **1.3**. Figure 2-5 presents a diagram of the benefits flow for data sharing on the surface. For more details on the SDF data sharing on the surface benefits flow (including detailed descriptions of the potential benefits) see *Performance Metrics Results to Date October 2003* [3]. Operational testing of the surface surveillance system to began in late 2004. Analysis of baseline taxi data and metrics can be seen in the *FAA SF-21 SDF Metrics Update January 2005* [8]. Results and analysis after implementation will be presented in future documents.

Figure 2-6 presents a diagram of the benefits flow for enhanced situational awareness/see and avoid in the terminal area. In *Performance Metrics Results to Date April 2003* [9], we presented the terminal area benefits flow and quantified the impacts where possible. In the following sections, we summarize the previous results from [1] and present an updated analysis of flight distance and times in the terminal area.

Figure 2-5. SDF Data Sharing on the Surface Benefits Flow

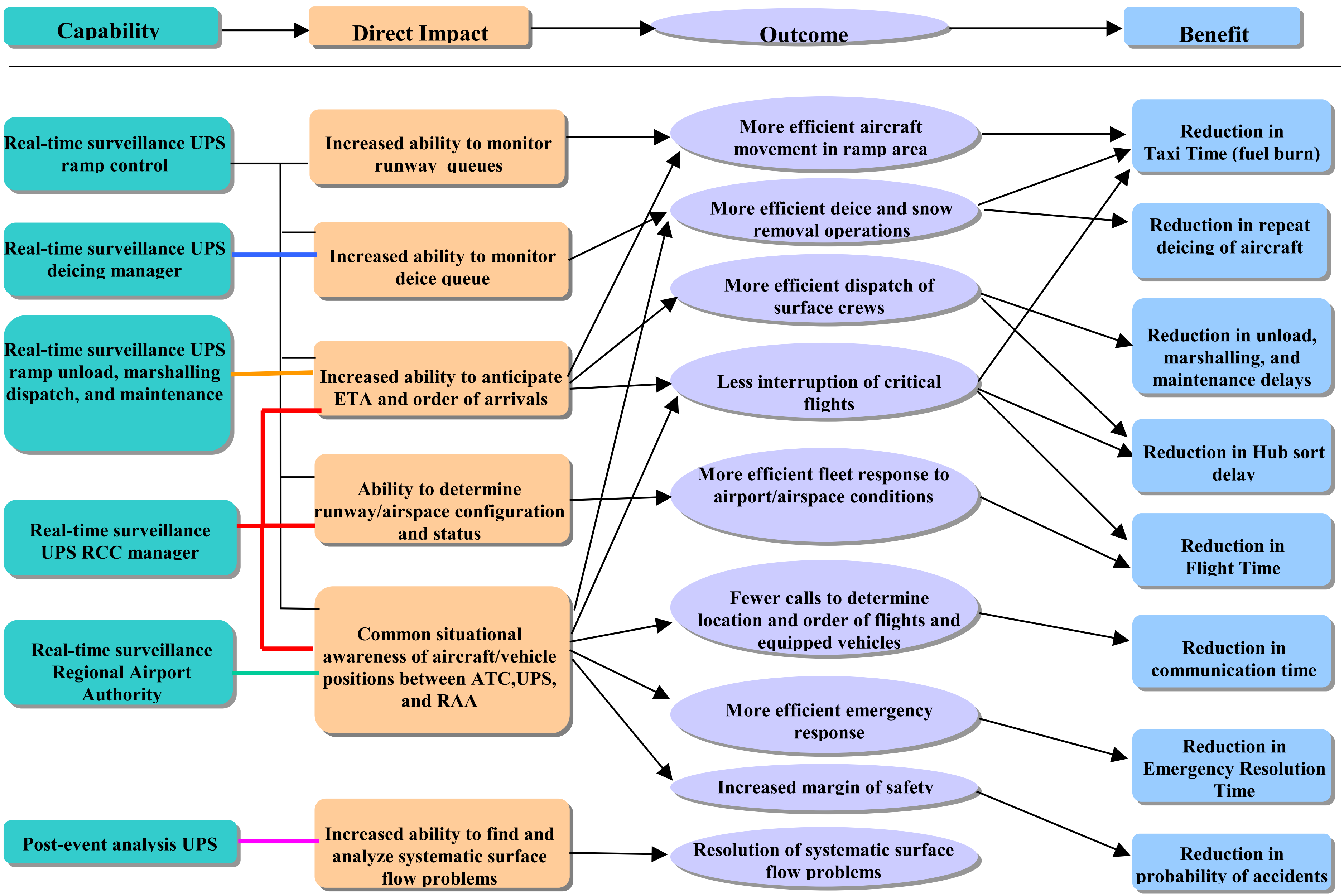
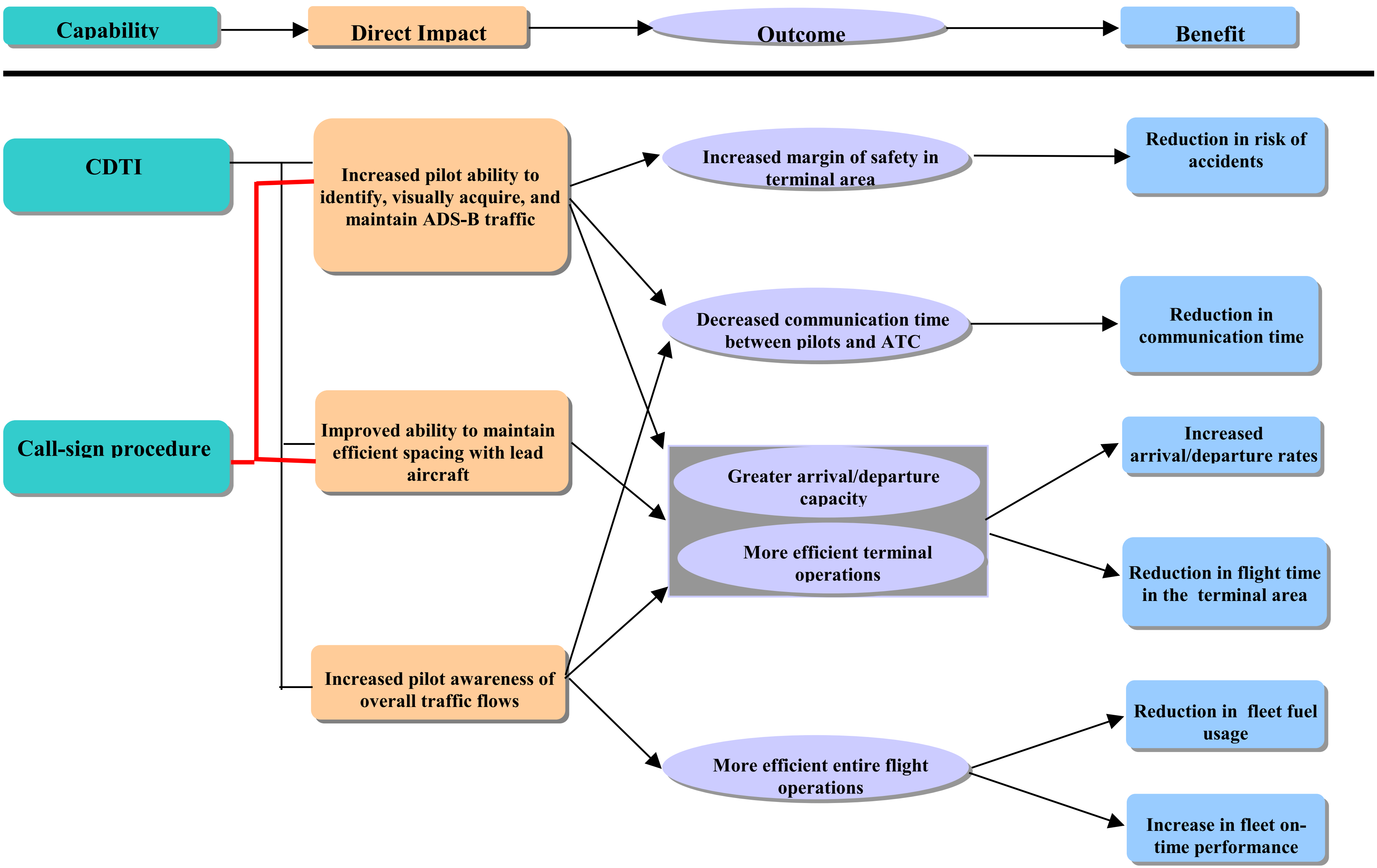


Figure 2-6. SDF Enhanced Situational Awareness/See and Avoid in Terminal Area Benefits Flow



2.3.1 Summary of Previous Results

The summaries below are organized by the benefits flow *outcomes* seen in Figure 2-6.

• Decreased communication time between pilots and ATC – We presented an analysis of audio loading on the ATC channels during the transition to ADS-B and after a majority of the UPS B767/B757 fleet had been equipped. As a measure of audio loading, we examined the total integrated area under audio loading curves. This is a measure of the total operator workload on the audio system. This total audio workload should decrease as the system becomes more efficient. The integrated audio loading for the ATC terminal frequency decreased approximately five percent in the post-implementation period.

• Greater arrival/departure capacity/More efficient terminal operations – We presented an analysis of flight times and distances for UPS arrivals into SDF. The results compared track data from the first three months of full CDTI equipage to the same three months from the year before. We update this analysis in the next section.

• More efficient overall flight operations – We presented an analysis of the difference between actual in-flight fuel burn and planned in-flight fuel burn for UPS arrivals into SDF. The results compared UPS fuel data from the first three months of full CDTI equipage to the same three months from the year before. The results showed a decrease in the difference between actual and planned fuel burn, indicating an increase in predictability. The mean percent difference of in-flight fuel burn (i.e. (actual-planned)/planned) decreased eleven percent after implementation. This analysis has not been updated because planned fuel burn numbers changed dramatically after UPS implemented new flight planning software in April 2004.

2.3.2 New Flight Distance/Time in Terminal Area Analysis

This analysis concerns the **Greater arrival/departure capacity and more efficient terminal operations** outcomes seen in Figure 2-6. Most of the benefits flow outcomes (especially the CDTI-related ones) also relate to specific CDTI applications outlined in the *Safe Flight 21 Master Plan* [4]. The current Master Plan application associated with greater terminal area capacity and efficiency is **Enhanced Visual Approach**. There are further Master Plan applications that focus specifically on efficiency during Instrument conditions. In the following subsections, we describe the mechanism for benefit in detail, and then present the analysis and results.

2.3.2.1 Benefit Mechanism Description

Visual Approaches (VAs) are the most expeditious, effective and efficient way to facilitate arriving air traffic, increasing airport capacity by as much as 50 percent over Instrument Landing System (ILS) arrivals. VAs allow Air Traffic Control (ATC) to transfer radar Instrument Flight Rules (IFR) separation responsibility (typically 3 miles-in-trail) to the aircrew, reducing separation between the same type aircraft (B-737, B-727, MD-80, A-320, etc.) to as little as 2 miles-in-trail. This procedure is well established (more than 30 years) and maximizes airport capacity while maintaining safety.

The ADS-B/CDTI **Enhanced Visual Approach** application helps to increase efficiency at the airport by allowing more VAs, and by allowing VAs to be flown in a more efficient manner. To further explain these benefits, we examine three ways in which a CDTI can directly affect user operations: (1) *Increased pilot ability to identify, visually acquire, and maintain sight of ADS-B traffic*, (2) *Improved ability to maintain efficient spacing with lead aircraft*, and (3) *Increased pilot awareness of overall traffic flows.* (Also see Direct Impact column of benefits flow, Figure 2-6.)

1) <u>Increased pilot ability to identify, visually acquire, and maintain sight of ADS-B traffic</u>

VAs require the flight deck crew (aircrew) to visually acquire preceding aircraft (aircraft they will follow) or the airport, prior to ATC issuance of the Visual Approach clearance. Once the VA clearance is issued, in-trail separation and maintaining visual contact with preceding traffic becomes the responsibility of the aircrew. If the aircrew cannot maintain this visual contact, it is incumbent upon them to advise ATC so another form of approved separation[1] may be achieved.

The ability of ATC to issue Visual Approaches is based on strict weather minimums. A weather ceiling of at least 500 ft. above the minimum vectoring altitude is essential for VA operations. For example, the VA weather minimums for SDF are a ceiling of 3000' and 3 miles visibility.

In many cases, however, conditions prevent ATC from operating at full VA capacity prior to reaching VA weather minimums. Weather ceilings determine VA minimums, however, pilot ability to identify and maintain visual contact with traffic and the airport surface (all critical elements in the VA) may be difficult at night or during times when scattered layers exist below the ceiling.

During peak arrival rushes, aircraft are sequenced to the airport at closely spaced intervals that allow very little opportunity for adjustment, minimizing options available to the ATC Specialist. If an aircraft cannot maintain VA separation criteria (cannot see preceding traffic), resulting in a loss of IFR separation, the aircraft is generally taken out of the final approach sequence and vectored again to the final approach course using standard IFR radar (miles-in-trail) separation. Due to airspace saturation, this is not only time consuming for the aircraft/airline, but also labor intensive for the ATC Specialist.

During such times, ATC specialists become preoccupied with traffic calls to establish visual contact between aircraft, resulting in a point of diminishing returns. To avoid compromising safety, ATC has established VA cutoff points that are, in many cases, above the VA weather minimum criteria. The value of the VA cutoff point is based on ATC Specialists' past experience, airport characteristics, and the point of diminishing returns.

The FAA Operational Evolution Plan (OEP) (see application AW-2.1 [10]) indicates the use of the CDTI is expected to assist the pilot in visually acquiring, identifying, and tracking an aircraft that has been referenced as traffic by ATC, so the controller may clear the aircraft for a visual approach. The CDTI accomplishes this enhancement by allowing

[1] Approved IFR separation is radar, non-radar, or visual.

the pilot to correlate the target aircraft and trajectory information from the CDTI to the actual traffic as seen out-the-window. Also, with faster identification of pertinent traffic, the need for additional traffic advisories by ATC or follow-on interactions between the pilot and controller is expected to decrease. We expect these changes to increase terminal area efficiency in VA conditions resulting in a reduction in flight time in the terminal area and an increase in arrival rates. No changes to FAA Order 7110.65 (Air Traffic Control) are required for this application.

The current ADS-B/CDTI terminal application is a critical building block for future applications eventually aimed at allowing ATC to continue VAs down to Visual Meteorological Conditions (VMC) minimums, which require ceilings greater than 1,000 ft and visibility greater than 3 miles.

2) <u>Improved ability to maintain efficient spacing with lead aircraft</u>

In current operations, pilots have no reliable means of determining the exact spacing behind the aircraft in front of them. Visual approach relies on the pilot's experience to avoid the preceding aircraft and aircraft wake, while maintaining sufficient space to ensure that the aircraft can clear the runway prior to his or her own landing. Historical studies have shown that there is a significant variation in the distances between aircraft in visual approaches [11]. The net result of such variations is excess spacing between some aircraft pairs; the accumulation of such excess leads to a lost opportunity to land additional aircraft during a period of peak arrival demand.

With CDTI, the pilot has a digital readout of range and an indication of relative ground speeds. This is expected to enable pilots to maintain better awareness of position and speed of traffic being followed and help the pilot judge more precisely the necessary control inputs to achieve a given spacing. The expected reduction in spacing variation would lead to the elimination of the lost throughput opportunities. We expect evidence of this increased efficiency to also result in a reduction in flight time in the terminal area and an increase in arrival rates.

3) <u>Increased pilot awareness of overall traffic flows</u>

The last CDTI impact we discuss is increased pilot awareness of the traffic flow into the airport. CDTI can display all ADS-B aircraft in the terminal area. Pilots can use this information to obtain a better idea of the overall arrival flow. This should allow the pilot to respond quickly to ATC instruction and prevent potential misunderstandings, thereby increasing efficiency. A recent email from an International Pilot Association (IPA) pilot to UPS management illustrates this point:

> "Well, I've seen the light…Last Friday night, I was flying into the SDF sort around midnight and the ADS-B/CDTI was showing almost all the inbound traffic as ADS-B equipped. The parade of inbounds could be easily seen on the screen. The reason for the occasional turn and/or speed reduction could be anticipated by a near radar-like view of the traffic surrounding us and the flow to the final segment (NAV function displayed on CDTI). The situational awareness of the ATC environment was dramatically increased…Pretty neat stuff."

2.3.2.2 Analysis Description

Our examination of terminal efficiency considers flight time and distance of UPS arrivals into SDF. We can directly relate flight time measurements to fuel burn, but the average flight time from day to day varies dramatically because of the wind. Flight distance measurements are less affected by the wind; however, they lack any speed change information.

Figure 2-7 displays flight tracks during a night of North Flow operations. The arrows point out rings at 40 nmi and 100 nmi from the airport center. We use these rings in the analysis to separate the flights into regions during approach. We also examined flight distances as far as 300 nmi from SDF, but found no measurable effect beyond 100 nmi.

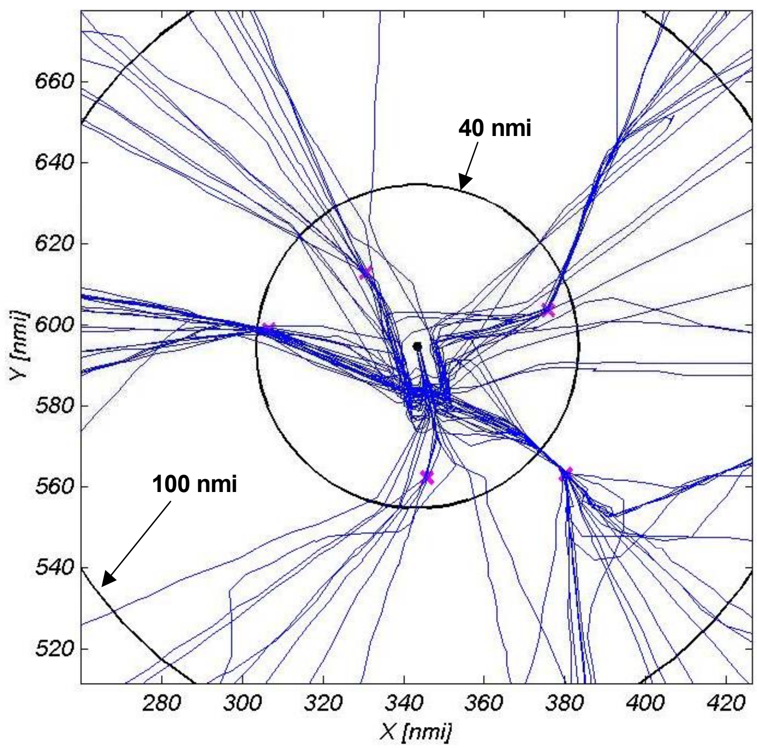


Figure 2-7. Example flight tracks during North Flow operations at SDF

The flight track calculations use three data sources. Flight tracks beyond 40 nmi use Enhanced Traffic Management System (ETMS) one-minute position data. This is data archived from the Air Route Traffic Control Center (ARTCC) Host computer system. The archived Host data is fairly accurate outside of the immediate terminal area (40 nmi), but suffers some signal loss inside of SDF TRACON airspace. Also, the many changes in speed and direction necessary for an approach may not be sufficiently captured by the one-minute tracks.

Flight tracks within 40 nmi employ two different ARTS archives. Before August 2003 we use compressed ARTS III-A data archived at the FAA Command Center. This data source became inactive after SDF installed ARTS III-E. After October 2003, we use data from the UPS SMA ARTS feed archived by JHUAPL on a monthly basis. To determine if these two archives give similar results, we compared the mean flight time and distance distributions for a day of overlap in May 2003. (We received a few days in May and June from the new data source before we were able to archive continuously). The results of the comparison found little statistical difference (well below the 95 percent level) in the flight time and distance means.

By Jan 2004, over 90 percent of the UPS B757/B767 domestic fleet included operating CDTI displays (See Figure 2-4). The B757/B767 fleet comprises 65 percent of the total UPS fleet. The metrics group decided that January 2004 would be a good starting point to observe the impacts of CDTI/Enhanced Visual Approach. The post-implementation data set begins January 1, 2004 and ends December 31, 2004. In the following analysis we compare the post-implementation data to two different baseline data sets (see Figure 2-8). Baseline Data Set 1 does not include data from the partial equipage transition period (June – December 2003). To take seasonal demand into account, we examine a full year of data before and after implementation; however, to avoid the partial equipage period, the baseline data set contains data from two different calendar years: June 2002 through May of 2003. Baseline Data Set 2 contains flights from January through December 2003, but overlaps the transition period.

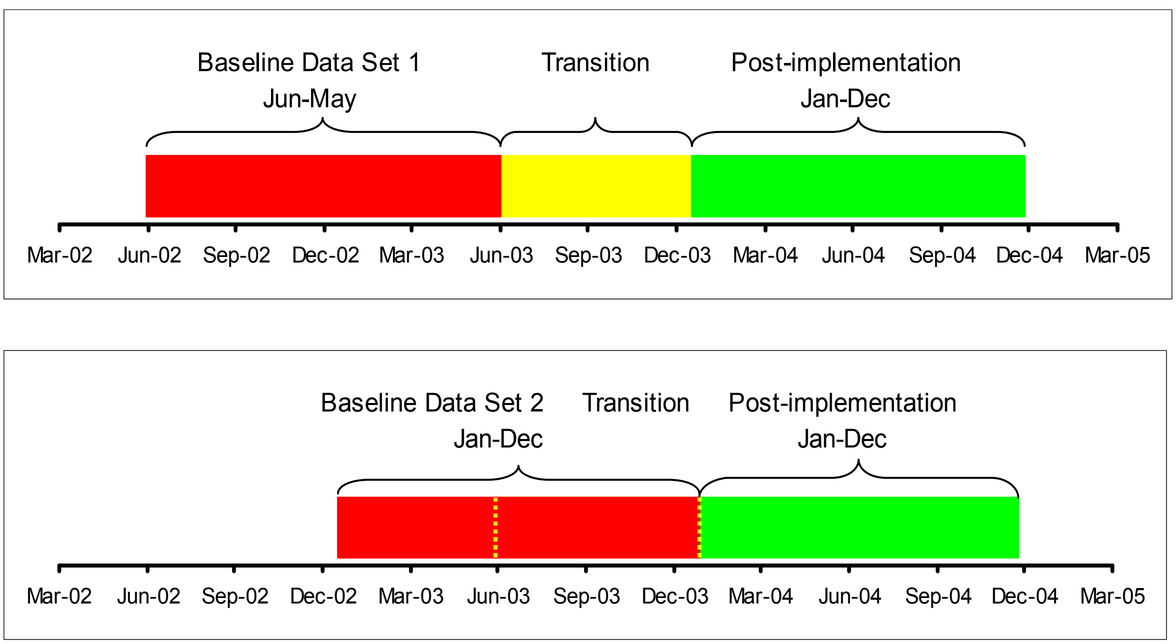


Figure 2-8. Timelines showing baseline and post-implementation data periods

First, we examine flight time and distance changes for the entire UPS fleet. Then, we narrow the focus to examine the period with the highest fraction of equipped aircraft. Figure 2-9 displays the number of SDF arrivals and the fraction of those arrivals that are B757s or B767s in 15-minute periods throughout a day. The shaded box in Figure 2-9 indicates the arrival peak with the maximum percentage B757/B767 traffic. This peak period occurs between 1:30 am and 2:30 am local time (between 2130 and 2230 GMT during Daylight Savings and between 2030 and 2130 otherwise.) CDTI use should affect the flow in both full and mixed equipage scenarios, but we expect the magnitude of the effect to be greater during times of high equipage. There were two other major changes (besides CDTI) that may have affected flight distances during the B757/B767 peak. From September 14, 2004 through September 26, 2004, flights during the high-equipage peak participated in a test of Continuous Descent Approach (CDA). Then, starting on December 8, 2004, UPS instituted a new arrival pattern for flights during this same peak. To focus our study on CDTI-related changes, we did not include data from the CDA test or after the start of the new arrival procedure in the post-implementation data set when examining changes in the peak period flights.

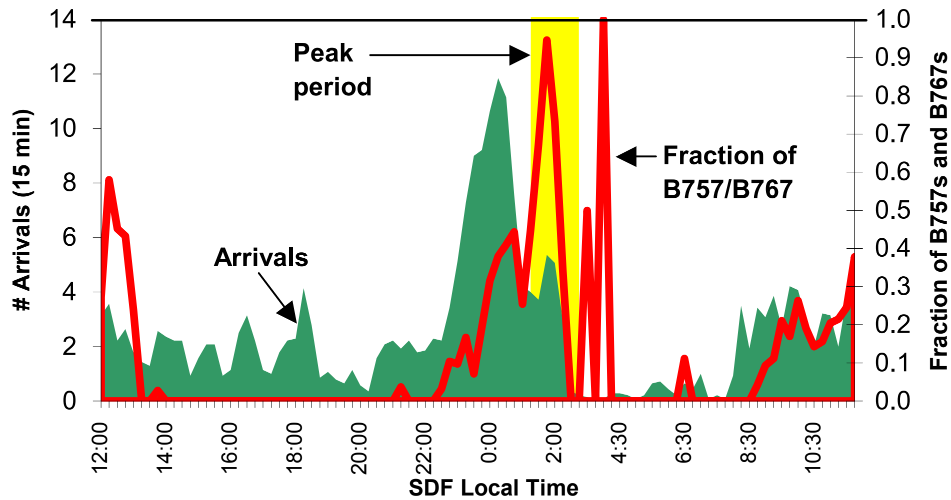


Figure 2-9. Average SDF Arrivals (15 min) and Fraction of B757/767s showing peak period

To take airport configuration into account, we bin the data by runway configuration. SDF primarily operates in one of two runway configuration modes: North Flow and South Flow. During a particular configuration, most of the flights arrive and depart facing the direction of the flow. SDF determines airport flow based on winds, runway conditions, and noise abatement procedures.

We separate weather data into instrument (IA) and visual (VA) approach conditions based on the time of arrival compared with weather reports from the Aviation System Performance Metrics (ASPM) database. Since we do not have access to actual approach records, we cannot be sure that visual or instrument approaches were being implemented at a specific time. However, we assume that a majority of the flights use instrument approaches during the defined IA conditions, and visual during the defined VA conditions. ASPM defines the conditions based on SDF facility input to be running IA when the ceiling is less than 3000 ft or the visibility is less than 3 nmi.

2.3.2.3 Analysis Results

Figure 2-10 displays the distance savings (difference in means between baseline and post-implementation periods) from 40 nmi to the runway using Baseline Data Set 1. There are separate results for all UPS flights, UPS flights during the B757/767 peak period, and non-UPS flights for comparison. We show results for each runway configuration/weather condition pair. All results represent differences in the mean values that are significant to at least the 95 percent level, as determined by an independent samples T-test. If a difference in the means was not determined to be significant to the 95 percent level, we did not include the value. Detailed statistical information is available upon request.

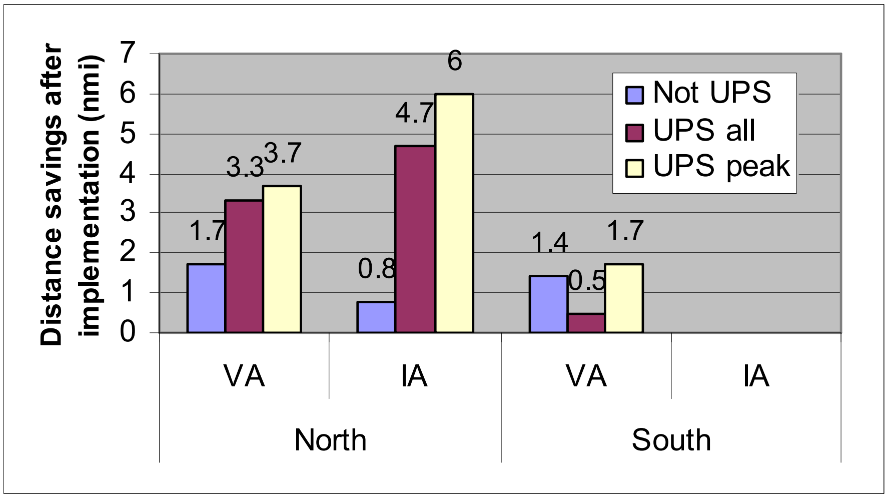


Figure 2-10. Flight distance savings 40nmi-runway using Baseline Data Set 1

For the North Flow configuration, we see significant flight distance savings for all UPS flights and UPS flights during the B757/767 peak in both weather conditions after CDTI implementation. As expected, the results for the high equipage case (UPS peak) are more dramatic than for the mixed equipage case. While the non-UPS traffic at SDF has also seen some savings, these savings are not as large as exhibited by the UPS flights.

During South Flow, the results are not as clear. There may be some flight distance savings for peak and non-Peak UPS flights; however, the non-UPS traffic also saw a similar savings. Also, no significant changes were found in South Flow IA conditions for any of the data sets.

Table 2-1 presents the flight distance and time values as well as the percentage of flights that flew during each runway configuration/weather condition pair. We believe the flight distance difference may represent a better estimate of savings than flight time; flight time values are heavily affected by local wind speed and direction. The percentage values can be used to gauge how often the savings are applicable. The data shows that North Flow is the dominant configuration during UPS operations and South Flow is the dominant configuration during non-UPS operations. This difference is due in large part to noise abatement procedures necessary for night operation at SDF.

Table 2-1. Flight distance and time savings 40nmi-runway using Baseline Data Set 1

Data Set 1	Metric	Non-UPS flights	All UPS flights	B757/767 peak UPS flights
VA North	**Dist Savings**	1.7 nmi	3.3 nmi	3.7 nmi
	Time Savings	31 sec	44 sec	31 sec
	% flights in config	29%	50%	59%
IA North	**Dist Savings**	0.8 nmi	4.7 nmi	6.0 nmi
	Time Savings	Not Sig	77 sec	74 sec
	% flights in config	9%	12%	13%
VA South	**Dist Savings**	1.4 nmi	0.5 nmi	1.7 nmi
	Time Savings	22 sec	Not Sig	Not Sig
	% flights in config	53%	32%	23%
IA South	**Dist Savings**	Not Sig	Not Sig	Not Sig
	Time Savings	Not Sig	Not Sig	Not Sig
	% flights in config	9%	6%	5%

Figure 2-11 and Table 2-2 present similar results using Baseline Data Set 2. The Data Set 2 results are not identical to the Data Set 1 results. The flight distance savings for all UPS flights appears to consistently 3.5 nmi for all condition-configuration pairs except Instrument Approaches-South Configuration. Also, there is not a large difference between savings for the high-equipage peak and the other UPS flights. The differences in results using Baseline Data Set 1 and Baseline Data Set 2 may indicate that the CDTI had already been affecting operations during the transition period (included in Data Set 2).

We also examined flight times and distances from 100 nmi to 40 nmi for both baseline data sets. While we saw some similar trends in the 100 nmi to 40 nmi data, the differences in the means were small and not statistically significant.

Results from both baseline data sets show a decrease in flight distances in the terminal area for UPS flights after CDTI implementation. These savings are most apparent during North Flow operations. The arrival peak with the highest equipage shows more dramatic savings than the mixed equipage periods for one of the baseline sets. The flight distance savings for UPS are significantly larger than for non-UPS flights at SDF during the period.

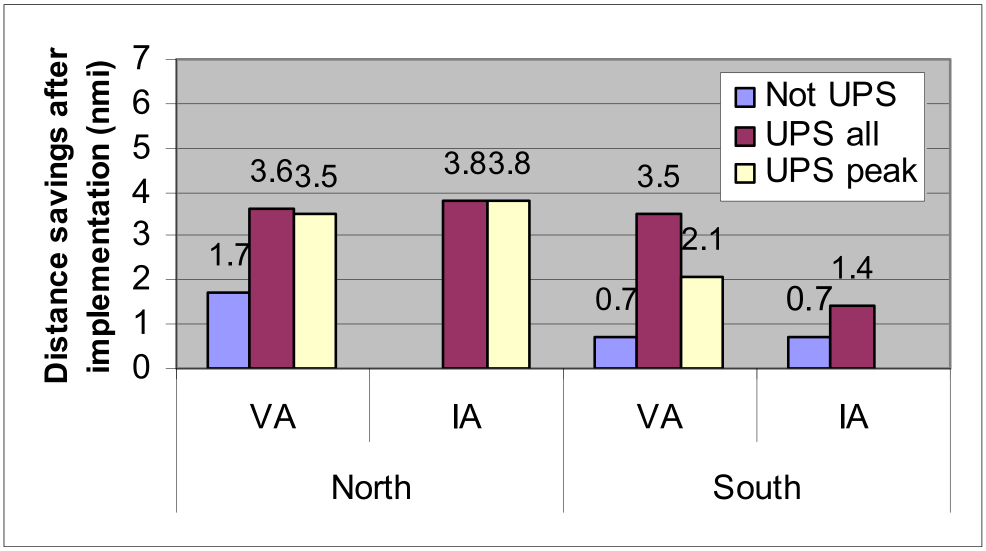


Figure 2-11. Flight distance savings 40nmi-runway using Baseline Data Set 2

Table 2-2. Flight distance and time savings 40nmi-runway using Baseline Data Set 2

Data Set 2	Metric	Non-UPS flights	All UPS flights	B757/767 peak UPS flights
VA North	**Dist Savings**	1.7 nmi	3.6 nmi	3.5 nmi
	Time Savings	34 sec	63 sec	41 sec
	% flights in config	28%	47%	55%
IA North	**Dist Savings**	Not Sig	3.8 nmi	3.8 nmi
	Time Savings	Not Sig	68 sec	44 sec
	% flights in config	9%	12%	13%
VA South	**Dist Savings**	0.7 nmi	3.5 nmi	2.1 nmi
	Time Savings	19 sec	71 sec	44 sec
	% flights in config	53%	34%	27%
IA South	**Dist Savings**	0.7 nmi	1.4 nmi	Not Sig
	Time Savings	14 sec	36 sec	Not Sig
	% flights in config	10%	7%	5%

To determine how exactly pilots are achieving benefits with CDTI, human factors experts from MITRE and NASA have been performing flight deck observations. Five flight segments were flown into or out of SDF with 16 traffic events. Preliminary results from these observations are summarized below.

The flight deck observations indicate that pilots actively use the CDTI but do not currently have many opportunities to use the CDTI to space themselves from another ADS-B aircraft on visual approach. However, when one flight crew member was attempting to join final behind another aircraft that was only displayed as a TCAS target, he stated his strong desire to have the additional information provided by ADS-B (e.g., traffic ground speed, direction of travel) to better judge his turn to final and to allow for sufficient spacing when on final.

Flight crews did use the CDTI for traffic awareness when monitoring the overall traffic flows in the terminal area and when predicting their position within that flow. One crew stated that they liked the awareness provided by being able to see a selected aircraft approach the field and fly along the runway extended centerline on the CDTI. Some flight crews also used the CDTI as a coordination tool when discussing the traffic situation and how it affected their flight. For example, flight crews were seen using the display when planning their arrival sequence when entering the terminal area.

As flight deck observations continue, further results will be presented to indicate specific mechanisms used to achieve the benefits shown in the flight distance/time data.

3.0 EAST COAST AND ERAU

3.1 System Description and History

The Future Surveillance Flight Safety Application Group focuses on stimulating production and self-equipage of ADS-B for the general aviation community.

Through agreements with several states along the East Coast, Future Surveillance provides ground infrastructure that supports ADS-B services. By the end of 2004, free traffic and weather information was available from 17 ADS-B ground stations in the contiguous U.S. (There are 11 additional ADS-B ground stations in Alaska as part of the Alaska Capstone Program.) This information is available to anyone equipped with ADS-B avionics.

To better examine the capabilities and benefits of ADS-B for GA, Future Surveillance supports a number of key sites where they hope to create a pocket of infrastructure and avionics large enough to positively affect operations in the near term. A major partner in this effort is Embry-Riddle Aeronautical University (ERAU) in Prescott, Arizona and Daytona Beach, Florida. Both the Prescott and Daytona Beach campuses began using ADS-B avionics (Garmin MX-20s) for most of their aircraft in late summer 2004. The installed avionics can display other ADS-B craft with associated call signs, non-ADS-B craft broadcast from the local TRACON, weather data, and map information. ERAU also received installations of the Comprehensive Real-time Analysis of Broadcast Systems (CRABS) tool for use in flight monitoring. Johns Hopkins Applied Physics Laboratory (JHUAPL) developed the CRABS software tool to record and display track information from ADS-B sensors.

3.2 Metrics Activities

In an effort to count increases in the number of current ADS-B users (GA and air carrier) that could use FAA broadcast services, JHUAPL monitors equipped aircraft from available sensors. They use data from sensors in Louisville, KY, and Atlantic City, NJ, as well as counts of known ADS-B aircraft and vehicles from ERAU, the Alaska Capstone program, and Milwaukee, MN. They measure unique identifiers detected on a monthly basis from aircraft and equipped ground vehicles.

Figure 3-1 displays the monthly count of unique identifiers from March 2004 through February 2005. The chart also indicates the ratio of aircraft to surface vehicles.

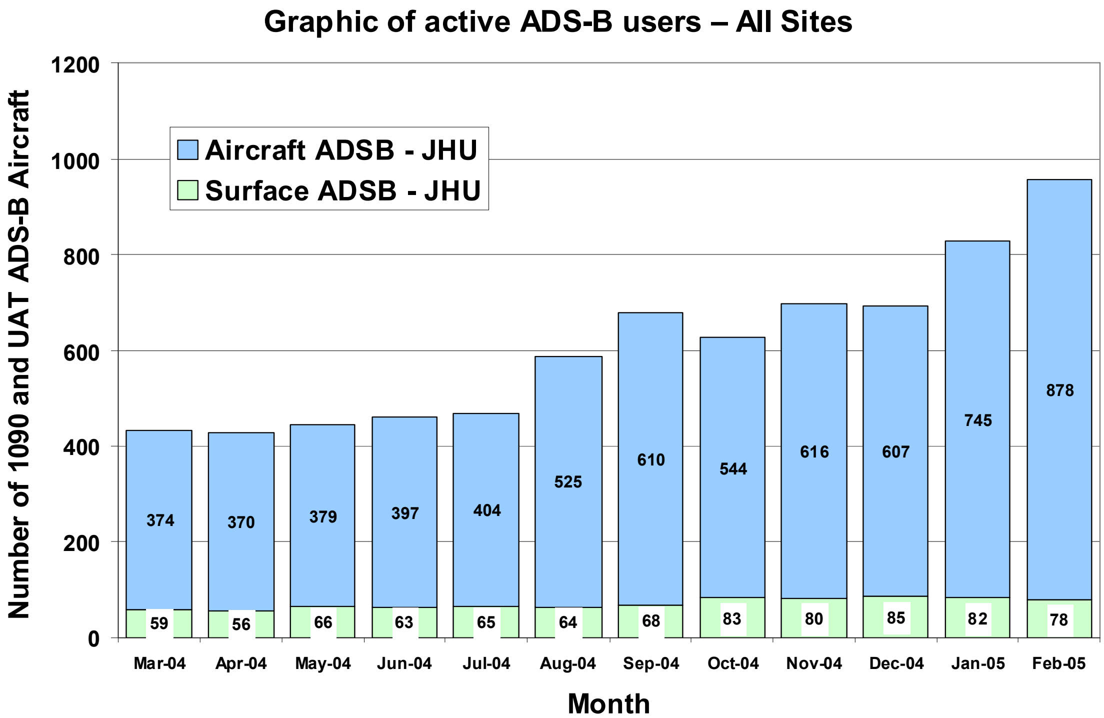


Figure 3-1. Number of observed ADS-B aircraft and vehicles from Mar 2004 through February 2005

The metrics team met with representatives of the Aircraft Owners and Pilots Association (AOPA) in November 2003 to discuss benefit descriptions for general aviation. The metrics team also visited ERAU at Daytona Beach in September 2004 to discuss gauging the impacts of ADS-B. ERAU already gathers much data that may be valuable as baseline data for the benefits process and has shared some of this data with Technology Development. We will begin analysis of changes in activity as use at these sites increases. In January 2005, ERAU at Prescott performed a survey of pilots who had used the MX-20 during operations. We present the survey and results in the next section.

3.3 Results

3.3.1 New Pilot Survey

To examine the operational benefits of ADS-B at ERAU, the flight manager at the Prescott campus developed a survey to elicit instructor reactions after using the display.

The 62 instructors were given 13 statements and were asked whether they Strongly Agreed (SA), Somewhat Agreed (SWA), Neither Disagreed nor Agreed (N), Somewhat Disagreed (SWD), Strongly Disagreed (SD), or the statement was Not Applicable (NA). Below is a list of the questions as they appeared on the survey:

1. Use of the MX-20 aided in visually acquiring traffic before receiving an ATC call.
2. Use of the MX-20 aided in visually acquiring traffic after receiving an ATC call.
3. ATC traffic, when visually acquired, appeared at the same clock position as depicted on the MX-20.
4. Use of the MX-20 had no effect on maintaining awareness of multiple targets.
5. Use of the MX-20 made sequencing on practice approaches safer.
6. Use of the MX-20 to enhance visual acquisition increased heads-down time.
7. Use of the MX-20 for traffic acquisition improved flight safety in the PRC Class D airspace.
8. Procedures for using the MX-20 to aid visual acquisition of traffic are effective.
9. The training received on use of the MX-20/ADS-B was sufficient to effectively utilize the equipment.
10. The MX-20 did not distract from crew duties.
11. Use of the MX-20 effectively enhanced my awareness of final approach traffic.
12. Overall, use of the MX-20 during ground operations increased my situational awareness.
13. Overall, implementation of ADS-B has enhanced flight safety.

Figure 3-2 displays the results. The chart is organized by percentage of positive response; the statements and statement numbers are listed on the left axis. All the instructors agreed that the display aided in acquiring surrounding traffic (statement 1) and enhancing overall safety (statement 13). The results also showed that a majority of the pilots thought that the system enhanced many of the other safety aspects. On the negative side, about 50 percent agreed that the display increased heads-down time (statement 6) and 30 percent thought the display distracted them from other duties (statement 10).

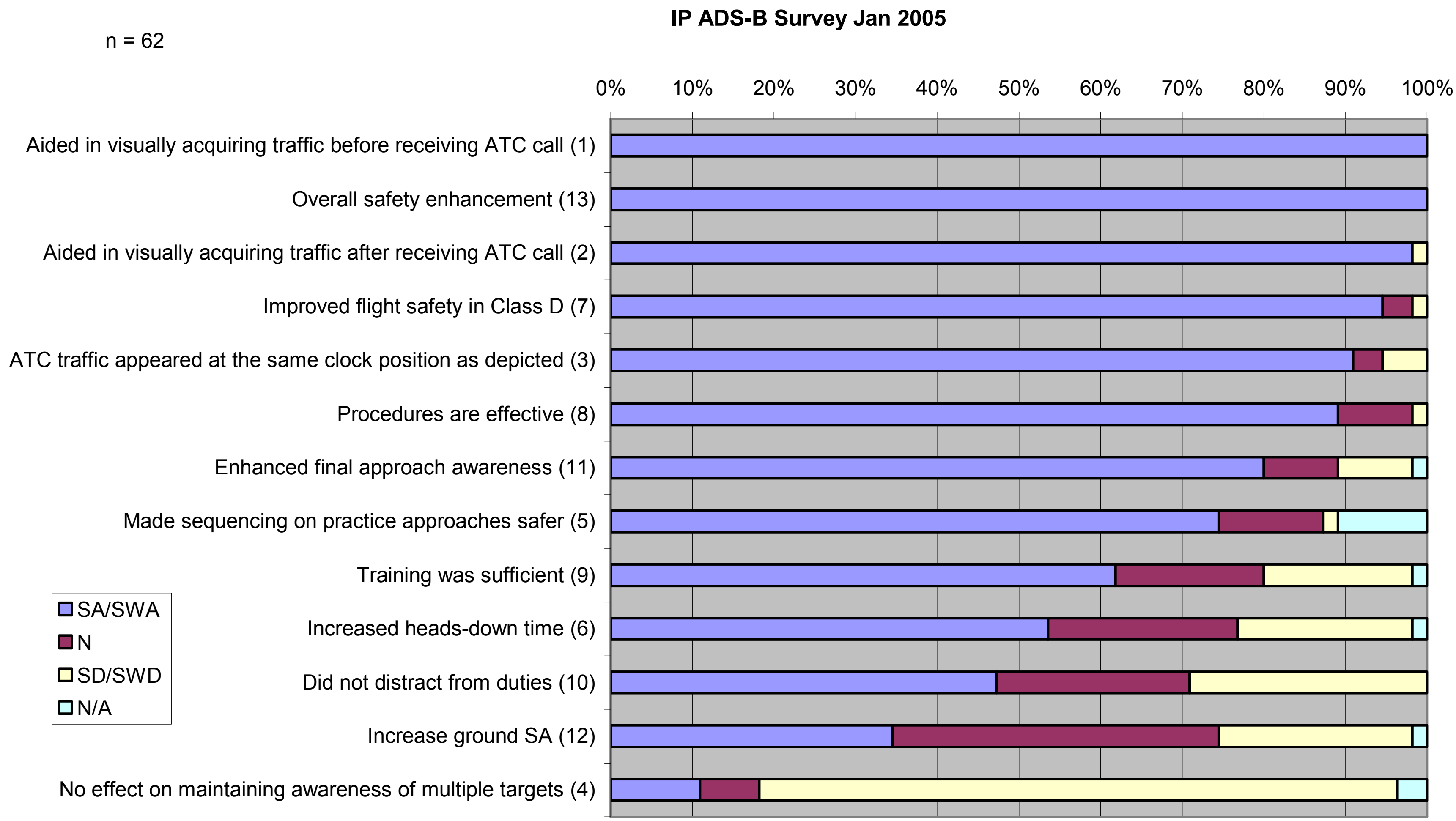


Figure 3-2. ERAU at PRC Survey Results

4.0 DFW RUNWAY STATUS LIGHTS

4.1 System Description and History

The Surface Systems Team supports the mission of the FAA's Runway Incursion Reduction Program (RIRP) by exploring, evaluating, and validating current and emerging technologies that show potential for increasing runway safety in the NAS. One of their current projects, the Runway Status Lights (RWSL) program, is a fully automatic advisory safety system designed to reduce the number and severity of runway incursions using fused surface surveillance data. Evaluation of an R&D version of RWSL is ongoing at Dallas-Fort Worth International Airport (DFW). In this section, we describe the current activities and summarize past projections about the effects of RWSL.

A runway incursion, as defined by the FAA Runway Safety Office, is any occurrence on an airport runway involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in a loss of separation with an aircraft taking off, intending to take off, landing, or intending to land.

Pilot deviations are the largest cause of runway incursions. The RWSL system should reduce the frequency and severity of runway incursions by improving situational awareness of pilots and vehicle operators through Runway Entrance Lights (RELs) that indicate a runway is unsafe to enter or cross. RELs illuminate red when a runway is unsafe to enter or cross due to a high-speed operation on the runway. See http://www.rwsl.net for more detailed descriptions, official notices to airmen, diagrams, and animations.

To provide the desired level of safety without impairing the efficiency of the controller, the timing of the lights is critical. Pilots should recognize that the RELs might be illuminated when the controller initiates a clearance, but they should be extinguished before the controller finishes issuing the clearance. The RELs turning off do not constitute a clearance to cross or enter a runway. The RWSL system is designed to provide a direct status indication to pilots that a runway is unsafe to enter or cross.

Shadow operations were performed in the DFW Air Traffic Control Tower in September of 2003 and June of 2004. An operational test is currently underway to probe the effectiveness of this tool at DFW. The test started in March 2005 and will continue through May 2005.

The RELs depend on surface surveillance infrastructure at both locations. At DFW, the system operates using position data from Airport Surveillance Radar (ASR-9) terminal radar, Airport Surface Detection Equipment (ASDE-3) surface radar, and a multilateration system (ASDE-Model X, or ASDE-X) that provides both surveillance and identification of all transponder-equipped aircraft and vehicles on the airport surface. In the next section (**Section 5**), we examine how the airlines have begun to use the multilateration surveillance data in their ramp areas.

Figure 4-1 presents a runway diagram of DFW with locations of in-pavement RELs marked with red bars.

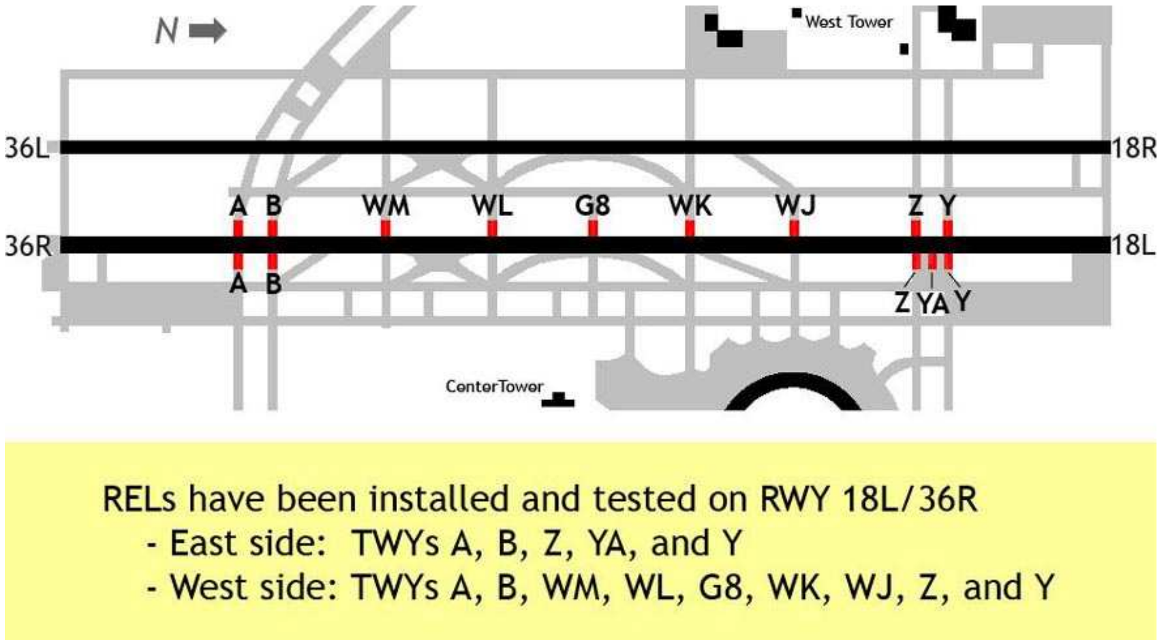


Figure 4-1. REL locations at DFW

As a possible follow-on program to RELs, the Surface Systems Team is examining Takeoff Hold Lights (THLs). THLs indicate to pilots in the takeoff hold position whether the runway in front of them is, or soon will be, occupied. They are illuminated red if the runway is not safe for takeoff; otherwise they are off.

More details concerning both RELs and THLs can be found in the RWSL Concept of Operations.

The Surface Systems Team also plans to test the RWSL system at San Diego International Airport (SAN). They are currently restructuring the SAN effort (which was previously managed outside of Technology Development) to enable implementation.

4.2 Metrics Activities

Before starting the RWSL installation at DFW, the FAA sponsored an examination of runway incursions focusing on those that might be prevented by runway status lights or tower-cab alerts [12]. The study categorized historical runway incursions at large airports and evaluated the potential effectiveness of elements of an automated airport safety system (RELs, THLs, and aircraft traffic display and alerts for the tower using the surveillance infrastructure). They judged that RELs and THLs, both used for pilot situational awareness, were the best defense against 65 percent of the historical incursions. In addition, 18 percent of the incursions may have been prevented with an aircraft traffic display and alerts available for the tower/cab controllers. In 17 percent of the cases, an automation-aided safety system would have offered little or no protection.

As mentioned is the last subsection (**4.1**), RELs are being operationally tested at DFW from March 2005 through May 2005. During this test, Technology Development has been administrating a pilot survey. In future documents, we will present the results of this survey.

5.0 DFW, DATA SHARING ACTIVIITES

5.1 System Description and History

A major enabler of the RWSL project at DFW (see **Section 4**) is the installation of an ASDE-X multilateration system. The FAA installed ASDE-X on the east side of DFW. NASA later installed ASDE-X on the west side as part of a data collection program. The Airport has been making these systems permanent in order to satisfy a commitment made to the FAA for mitigation of visibility restrictions to the Center Airport Traffic Control Tower caused by airport development. The ASDE-X provides both surveillance and identification of all transponder-equipped aircraft and vehicles on the airport surface. The DFW ASDE-X installation demonstrates the performance and effectiveness of current multilateration surveillance technology. The installation also serves as a long-term test bed for runway safety technologies.

In March 2002, the FAA gained the support of American Airlines, Delta Air Lines, and the DFW Airport Board to determine potential benefits in efficiency and safety associated with surface surveillance data sharing. The FAA agreed to provide a real-time multilateration data feed to the participants along with the necessary equipment, communications links, and training. The prototype multilateration data sharing began in May 2002 and became available for consistent use in November 2003.

Surface surveillance displays are currently located in the American Airlines Systems Operations Center (SOC), the American Airlines ramp tower, the American Airlines Headquarters, the DFW Airport Board operation center, NASA Ames, and the DFW Airport Emergency Operations Center (EOC). Displays for FAA users in the DFW ATC control towers, and in the TRACON will be available when the ASDE-X system is commissioned.

While the FAA will continue to share data from ASDE-X with the airlines and the airport board at DFW indefinitely, FAA funding for airline and airport board equipment, communication links, and training ended in December 2004. At that time, the airlines and the airport board negotiated with individual contractors as necessary to continue operations.

5.2 Metrics Activities

In December 2003, we held a meeting with all the interested parties to discuss the operational impact of surface surveillance data sharing. The attendees included representatives from American Airlines, Atlantic Southeast Airlines (a Delta subsidiary), Dallas/Fort Worth Airport, Delta Air Lines, the NASA North Texas Station (NTX), the FAA, associated contractors, and union representatives. Attendees explained the direct impact of each shared data capability and discussed the potential benefits that arise from these impacts.

We found that in addition to the surface surveillance data, American and Delta also had some access to shared terminal area flight data through a Center TRACON Automation System (CTAS) feed provided by NASA. The CTAS displays aircraft tracks close to the airport and estimated runway (On) times. This data can be used to accurately estimate gate (In) times. Because the CTAS and surface surveillance displays have similar benefit mechanisms, we examine both within this study. NASA performed a study of the use of CTAS in the American Airlines Systems Operations Center (SOC) in 1999[13] and a study of the CTAS display in the Delta ramp tower in 2002[14]. We list results from both of these studies where appropriate.

In March 2004, we visited American Airlines, Delta Air Lines, and the DFW Airport Board separately to discuss ongoing use of the tools and analyses. We revisited American Airlines and Delta Air Lines facilities in September 2004 to receive an update of surveillance activities. For unrelated financial reasons, Delta Air Lines discontinued use of their DFW hub operation in January 2005. As part of this change, Delta no longer control the Terminal E ramp traffic.

5.3 Results

After the initial metrics meeting, we developed a benefits flow. For an explanation of the benefits flow process see section **1.3**. We created separate benefits flows for the airlines and the airport board because they had somewhat different uses of the tool. Figures 5-1 and 5-2 display the graphical representations of the benefits flow for the airlines and the airport board, respectively.

In *Performance Metrics Results to Date April 2003* [9], we presented the benefits flow and attempted to quantify the impacts where possible. Below, we summarize the previous results from [1,2,3,9], and update current operational tests by American Airlines.

5.3.1 Summary of Previous Results

The summaries below are organized by the benefits flow *outcomes* seen in Figure 5-1.

• More efficient aircraft movement in the ramp area – We presented an analysis of taxi-out times for Delta Air Lines before and after implementation of surface surveillance in the ramp tower. The analysis used four months of baseline and post-implementation data. The results showed that in Visual Approach conditions (VA), Delta taxi-out times decreased on average 30 seconds per aircraft. This decrease in times was more impressive when one considered that taxi-out times for the other airlines at DFW during the same period increased by at least a minute. We also summarized results from past NASA studies [12,13] that examined the accuracy of estimated runway On times and gate In times before and after the implementation of CTAS in the American SOC and the Delta ramp tower. The increase in accuracy positively affects the ability of controllers to pre-plan arrivals and departures in the ramp area.

Figure 5-1. DFW Data Sharing Benefits Flow - Airlines

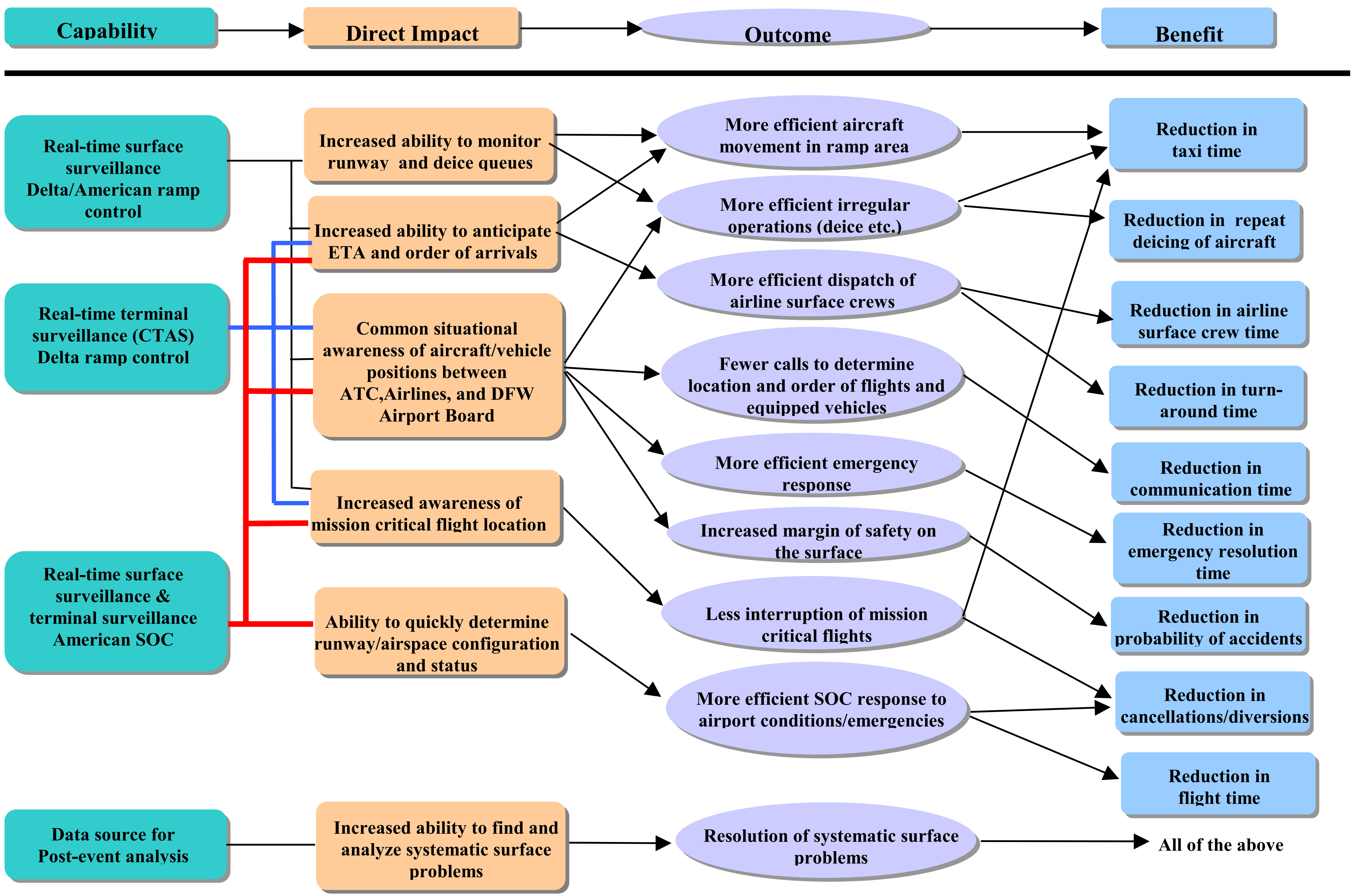
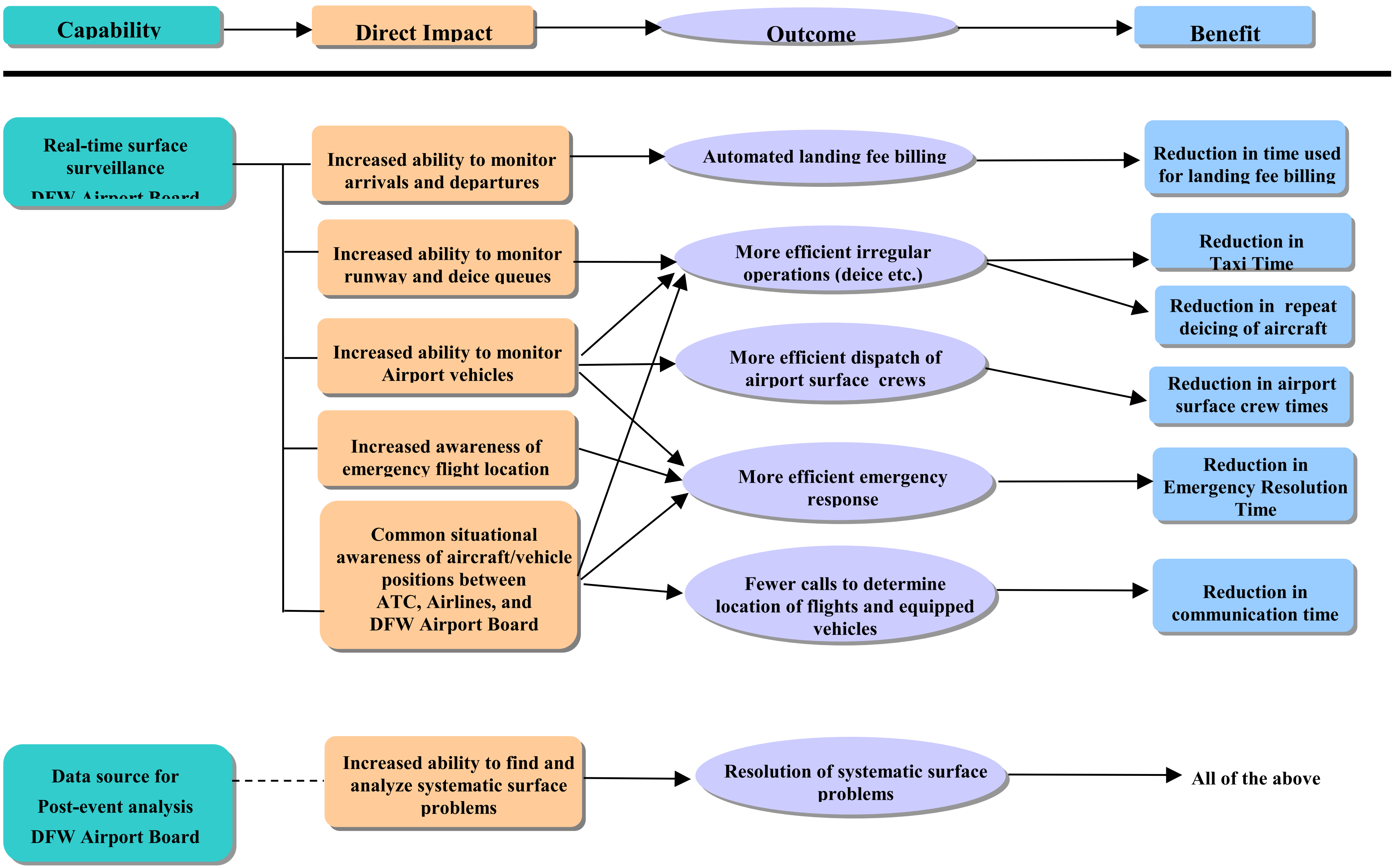


Figure 5-2 DFW Data Sharing Benefits Flow – Airport Board



• More efficient dispatch of surface crews – The inclusion of surface surveillance supported a change at the DFW Delta ramp from gate-based operations to task-based operations. Instead of a surface crew being responsible for the operations of one gate, the crew is tasked on an as needed basis at any number of gates. This system depends on the ability of the ramp tower to accurately determine aircraft locations in real-time, as provided by the CTAS and surface surveillance displays.

• Fewer calls to determine location and order of flights – Delta reported that they decreased the number of calls between pilots and the ramp tower during an arrival from two to one. They credit the reduction in calls to the availability of accurate landing information from CTAS and a reduction in non-ACARS aircraft.

• Less interruption of mission critical flights – We listed anecdotes from past NASA studies that examined diversion prevention and reaction time to diversions due to CTAS display use.

• Resolution of systematic surface flow problems – We mentioned that American Airlines installed three new surface surveillance displays in their headquarters building to examine surface tracks for use in analysis.

5.3.2 Future Application Descriptions

The Operations Engineering department of American Airlines began a new effort to find uses for its ASDE-X feed in late summer 2004. They described the following two applications as near-term activities.

Surface route communication

After landing at DFW, aircraft are under local FAA ATC Tower management until they are handed off to airline ramp controllers at specified ramp area entry points. Currently, American Airlines arrivals at DFW must contact the ramp tower to receive proper ramp area entry point location and gate assignment. American is trying to incorporate the ASDE-X feed in their ramp tower to proactively choose the most efficient ramp entry point, and transmit this information to the pilots via ACARS message. This application should reduce radio chatter between airline ramp controllers and pilots, and help to optimize flows on the surface.

Priority Queuing

American Airlines is the dominant carrier at DFW. During many busy times, most or all of the aircraft waiting in the first-come first-serve departure queues are within the American Airlines fleet. During these times, it would be economically beneficial to realign or insert flights with respect to priority or current delay. Since this insertion or reshuffling of aircraft is not in the airline ramp control area, ramp controllers must ask permission to make such maneuvers from the FAA Tower. American believes the ASDE-X display will allow airline controllers the opportunity to detect when insertion of priority flights is reasonable. The display should also provide a common situational awareness between the airline and the FAA ramp tower that should foster cooperative queue management.

6.0 VGT

6.1 System Description and History

As indicated in previous sections (**Sections 4,5**) the FAA Surface Systems Office is conducting research to identify new airport visual aids that may increase overall airport surface safety and prevent runway incursions. This research includes an Enhanced Airport Lighting (EAL) research and development project to assess the use of runway guard lights (RGLs) as runway incursion prevention tools.

RGLs have been part of the NAS since 1992. These flashing yellow lights located at the runway holding position provide visual cues that alert both pilots and vehicle operators that they are about to enter a runway. The current FAA requirement is to use RGLs with less than 1200 feet runway visual range (RVR) as a part of the Surface Movement Guidance and Control System (SMGCS). The EAL project has been undertaken to identify any potential benefits that may be obtained by using RGLs under non-SMGCS conditions, specifically to increase situational awareness.

The EAL project promotes the use of airport visual aids to increase overall situational awareness on the airport surface, more specifically in the airport movement area. The current standard for visual cues to help pilots identify runway holding positions includes painted surface holding position markings and holding position signs. In some cases, various airport configurations, visibility conditions, and other obstructions may complicate a pilot’s ability to determine the location of the runway holding position. To address these conditions, the EAL project has two goals: (1) to identify additional visual aids to increase pilot’s ability to recognize the runway holding position and (2) to identify technologies that will increase overall situational awareness at our nation’s airports.

The Surface Systems Office installed a test EAL system at North Las Vegas Airport (VGT). The system consists of three different configurations of runway guard lights:

- Elevated runway guard lights;
- In-pavement runway guard lights; and
- In-pavement “T” configuration of runway guard lights.

The Surface Systems Office coordinated decisions about the type of RGL system to install at each intersection with the airport.

The lights are collocated with the standard runway holding position paint markings and signage at all 29 runway/taxiway holding positions throughout the entire airport as displayed in Figure 6-1. Full details regarding placement and light specifications may be found in the *System Assessment Summary Report for the Enhanced Airport Lighting (EAL) System* [15].

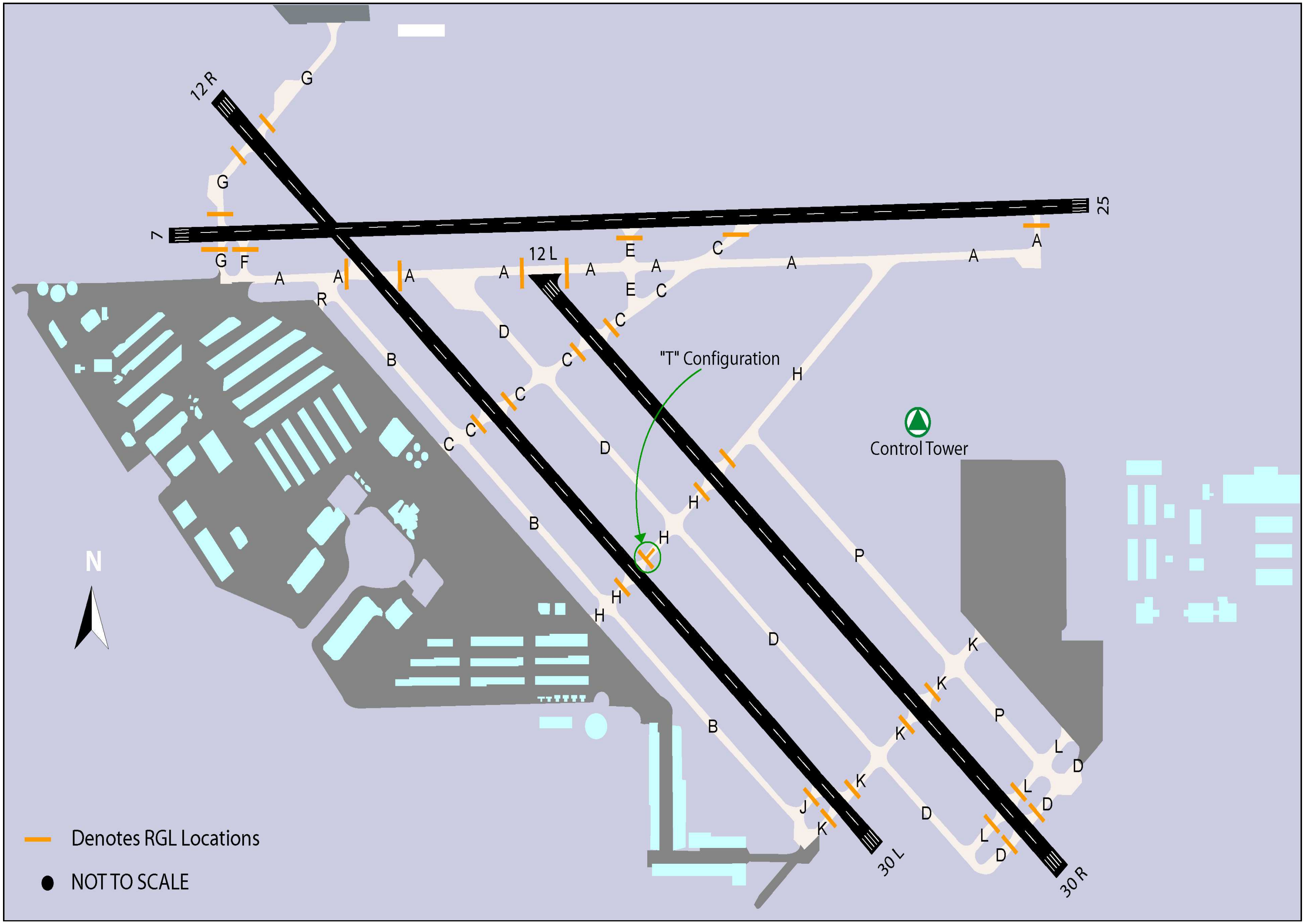


Figure 6-1. Enhanced Airport Lighting System - General Layout for North Las Vegas Airport (VGT)

In-pavement RGLs are centered on an imaginary line that is parallel to, and 2 feet (610mm) from, the holding side of the runway holding position marking, as shown in Figure 6-2.

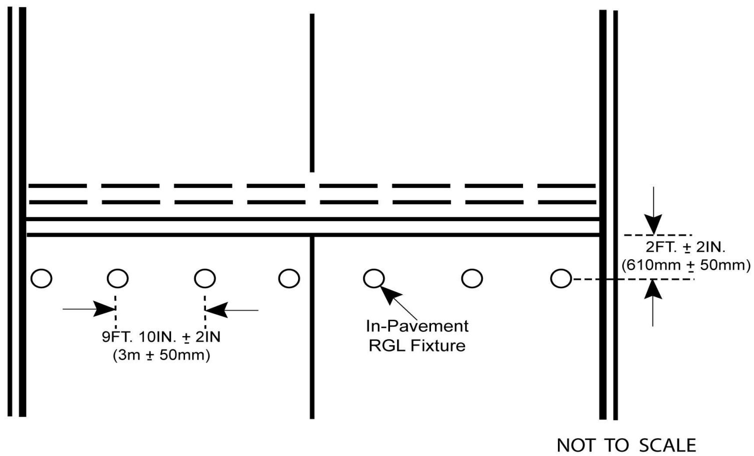


Figure 6-2. In-Pavement Runway Guard Light Configuration

Elevated and in-pavement RGLs serve the same purpose and both may be installed at the same runway holding position. Each elevated RGL fixture consists of two alternately illuminated, unidirectional yellow lights. Elevated RGLs are collocated with the runway holding position marking and are normally installed on each side of the taxiway (See Figure 8-3). The RGL should be located such that it does not interfere with the readability of the runway holding position sign.

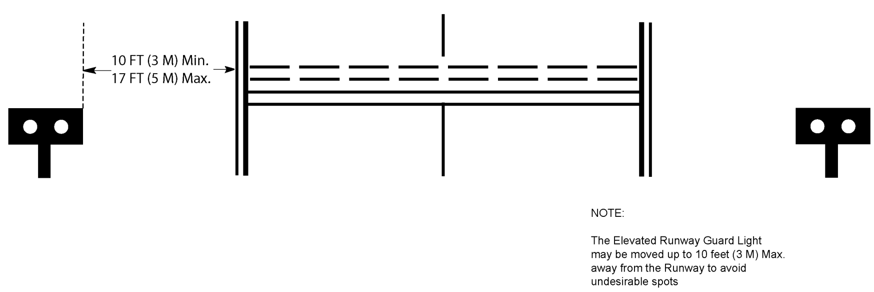


Figure 6-3. Elevated Runway Guard Light Configuration

One unique feature of the test system configuration at VGT is the addition of the experimental "T" configuration, as shown in Figure 6-4 at one single trial intersection. This entirely new application of conventional in-pavement RGLs is intended to define an alert zone, extending from the holding position markings on the taxiway away from the runaway for a distance of up to 200 feet. Its purpose is to illuminate the taxiway centerline with a series of up to four in-pavement RGLs spaced at fifty-foot intervals alongside the painted taxiway centerline. The actual installation at VGT requires only two additional in-pavement RGLs since the approach distance is limited.

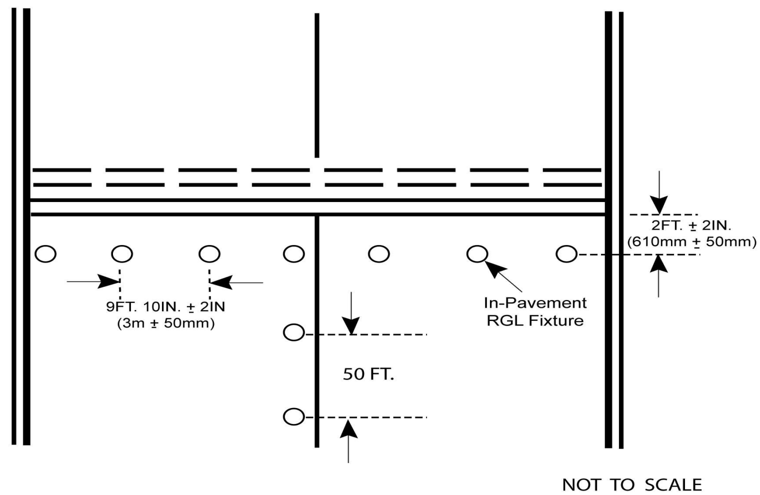


Figure 6-4. "T" Configuration of In-Pavement Runway Guard Lights

For aircraft approaching the holding position markings, the "T" configuration will act as an early warning that the holding position is ahead. It will also enhance the holding position itself, since it ends exactly at the painted holding position markings. It is anticipated that this configuration if accepted will be most beneficial when used on curved taxiways where the visibility of the hold line is hindered due to the taxiway geometry.

6.2 Metrics Activities

In January, August, and September of 2004, the Air Safety Technology Office of the William J. Hughes Technical Center performed controlled pilot acquisition tests of runway hold locations with and without RGLs at VGT. The tests quantitatively demonstrated increases in pilot acquisition range with the addition of RGLs. Pilot surveys also indicated positive reaction to the RGLs.

In addition to the test at VGT, the EAL Team conducted an overall data assessment of other airports that have RGLs. By looking at the runway incursion history of these airports both before and after RGL installation, several trends are apparent. Although the total number of incursions was not reduced, the severity of incursions decreased after RGL installation. The data shows fewer Category A and B incursions, with a corresponding increase in Category C or D incursions.

In the next subsections, we present a summary of the analysis and results mentioned above.

As a result of the findings derived from the above efforts, the EAL Team offered a series of recommendations:

1. The FAA application of RGLs should be modified to include their use as a runway incursion prevention tool independent of weather conditions.
2. Airports that currently have RGLs should turn them on during all operations.
3. RGLs should be powered during installations such that they can be operated independently of other lighting systems.
4. The FAA should consider making RGLs available to airports specifically for runway incursion prevention when recommended by the local Runway Safety Action Team (RSAT).

6.3 Results

6.3.1 New Tech Center Test Results

A preliminary evaluation was conducted during the period January 26 to 29, 2004 by AAR-411 personnel to collect baseline data relative to the acquisition distances for holding position signs and markings at seven specific runway holding position locations. The data collected during that evaluation was summarized and included in a quick look report titled *Evaluation of Runway Guard Light Configurations at North Las Vegas Airport –Phase One "Quick Look" Report* [16]. The purpose of this evaluation was to collect data at the seven test locations prior to planned construction activity that would include installation of RGL systems at all runway entrance locations.

Another evaluation was conducted during the period August 22 to 27, 2004 to collect additional sign and marking baseline data relating to acquisition distances at the original seven locations and at two additional locations that were identified as critical by the VGT Air Traffic Control Manager. This data collection included the Fixed Base Operators (FBOs) at VGT. In all, there were 1,980 data points collected. The data collected during that effort has been analyzed and included in a report entitled *Evaluation of Runway Guard Light Configurations at North Las Vegas Airport – Phase Two "Quick Look" Report* [17].

The final evaluation was conducted during the period September 20 to 24, 2004 to collect additional sign and marking baseline data relating to acquisition distances at the nine locations that were identified as critical by the VGT Air Traffic Control Manager. This data collection included the FBOs at VGT. In all, there were 42 subject pilots involved in this third phase of the evaluation. The data collected during that effort has been analyzed and included in a report entitled *Evaluation of Runway Guard Light Configurations at North Las Vegas Airport – Phase Three Report* [18]. The purpose of this evaluation was to collect data at the nine test locations with the RGL system activated.

Data for this test consisted of pilot evaluation data sheets and interviews. Analysis was performed on the survey and interview data to determine differences in holding position acquisition distance. The test vehicles included either a van equipped with a Beechcraft King Air 250W taxi light or a van equipped only with standard headlights. During Phase One, an aircraft was also used. During Phase Three, only standard headlights were used on the vans. In all cases, the test vehicles were taxied through the test course while the test subject attempted to acquire and identify the holding position lights, signs and paint markings at each location along the route. Identification of each sign (i.e. reading of the legend) was deemed necessary due to the fact that, especially at night, several different holding position signs might be seen (acquired) from a single observation point. The painted markings were considered as "identified" whenever the dashed portion of the marking configuration could be discerned.

All acquisition ranges shown in Table 6-1 represent the direct distance from the observer to the target (lighting component, signage or paint marking) at the point first identified. Variations in the data can be attributed to numerous factors such as orientation of the hold position relative to the sun, variations in pavement slope, and condition of paint markings.

Table 6-1. Enhanced Airport Lighting Acquisition Distance Data

	Phase 2 Before Lights w/ New Surface Paint Acquisition Distance (FT)				Phase 3 RGLs System Activation After Acquisition Distance (FT)				Acquisition Distance Improvement (FT)				Safety Improvements % Change in Acquisition Distance (Testing conducted with RGLs at 30% of full intensity - step 2)			
	Dawn	Day	Dusk	Night	Dawn	Day	Dusk	Night	Dawn	Day	Dusk	Night	Dawn	Day	Dusk	Night
Delta 1	**480**	**465**	**403**	**394**	**776**	**310**	**852**	**836**	**296**	**-155**	**449**	**442**	**62%**	**-33%**	**111%**	**112%**
Delta 2	522	581	486	472	607	352	936	678	85	-229	450	206	16%	-39%	93%	44%
Delta 3	358	498	393	426	580	260	1030	907	222	-238	637	481	62%	-48%	162%	113%
Hotel 1	**1041**	**1075**	**792**	**725**	**1223**	**1252**	**1358**	**1224**	**182**	**177**	**566**	**499**	**17%**	**16%**	**71%**	**69%**
Alpha 1	984	991	641	559	1734	1546	1764	1729	750	555	1123	1170	76%	56%	175%	209%
Alpha 2	321	330	217	215	217	178	424	417	-104	-152	207	202	-32%	-46%	95%	94%
Alpha 3	580	571	575	581	580	571	575	581	0	0	0	0	0%	0%	0%	0%
Alpha 4	858	901	844	642	858	988	974	982	0	87	130	340	0%	10%	15%	53%
Golf 1	470	567	595	562	470	571	595	579	0	4	0	17	0%	1%	0%	3%

Notes:

- Data from Controlled Study Quick Look Reports.
- Testing was done with RGLs on Step 2, VGT currently operating on Step 3 (100% intensity) for Dawn and Day.

6.3.2 New Pilot Interview Study

In addition, a total of 33 pilots completed a post-session questionnaire expressing their opinion as to the effectiveness and relative need for each of the holding position indicator configurations. Questionnaire results, expressed as a percentage of the 33 ratings obtained for each question, are provided on the questionnaire summary form located below (Figure 6-5).

ELEVATED RUNWAY GUARD LIGHT EVALUATION

EVALUATOR POST-SESSION QUESTIONNAIRE

(Final Evaluation)

Date:_9/21-23/2004_ Name:__33 Respondents_______ Time:__All Sessions__

Please rate the value of the visual aid components of the Enhanced Airport Lighting (EAL) system that you are presently evaluating. This a subjective evaluation and, as such, we are relying on your aviation background and experience to provide us with your best opinion on the matter. We are asking you to address and evaluate each component, in turn, for it's effectiveness in identifying the runway/taxiway holding position.

1. Basic Red/White Lighted Sign:

Essential:_85%_ Very Useful:_15%_ Convenient:_0%_ Unnecessary:_0%_

2. Basic Red/White Non-Lighted Sign:

Essential:_36%_ Very Useful:_64%_ Convenient:_0%_ Unnecessary:_0%_

3. Painted Markings:

Essential:_82%_ Very Useful:__6%_ Convenient:_9%_ Unnecessary:_3%_

4. Elevated Runway Guard Lights:

Essential:_52%_ Very Useful:_33%_ Convenient:_12%_ Unnecessary:_3%_

5. In-pavement Runway Guard Lights:

Essential:_27%_ Very Useful:_43%_ Convenient:_30%_ Unnecessary:_0%_

6. In-pavement Alert Zone "T" Configuration:

Essential:_27%_ Very Useful:_39%_ Convenient:_30%_ Unnecessary:_3%_

7. Of the visual components viewed, which do you rank as having the most effectiveness?

Markings:__8%__ Signs (Lighted):_26%__ Signs (Non-lighted):__2%_

Elevated RGL:_60%__ In-pavement RGL:__2%_ Alert Zone "T":__2%_

Figure 6-5. Questionnaire Responses in Percentage

6.3.3 New Runway Incursion Rate Analysis

To estimate the operational benefits of the Enhanced Airport Lighting system at North Las Vegas Airport, runway incursions at other airports were examined. Specifically, the study considered runway incursions at the top 39 runway incursion airports between 1998 and 2003 as listed in Department of Transportation (DOT) report number AV-2003-040 [19]. Twenty-three of the 39 airports (or 58 percent) had at least a partial installation of RGLs installed between 1998 and 2003. RGL use has been sporadic across the nation with installation and even operational decisions being made only at the local level without the benefit of a national standard or coordinating authority. Each of the airports was contacted separately to determine when, or if, RGLs had been installed and how they were used operationally.

To normalize the data across such a wide range of airports, the runway incursion rate was used as the principal metric. This rate is determined by dividing the number of incursions by the number of flight operations for a given airport. The FAA Runway Safety Office also ranks runway incursions by severity. Category A is the most severe and category D is the least severe. The rankings add more granularity when assessing the surface safety. Even when the total number of incursions remains about the same, a clear reduction in the severity of the incursions can indicate an increase in safety. The runway incursion rate (RI) and the runway incursion severity categories used in this study came from the *FAA Runway Safety Report -Runway Incursion Trends and Initiatives at Towered Airports in the United States, FY 2000 – FY 2003* [20].

It is recognized that pilot situational awareness is not a factor in every runway incursion. Accordingly, technology insertion such as the Enhanced Airport Lighting system is not the only solution. Both training and flight deck resource management are two additional factors that can play important roles in reducing the incidents of runway incursion.

Figure 6-6 displays the runway incursion rate between 1998 and 2003 for 39 airports grouped into three lines: those without RGLs (None), those with RGLs placed at certain hotspots (Hotspots), those with a full installation of RGLs at all crossings (All). Since installation of RGLs occurred during the time studied, the number of airports in the three groups changed. For each year in Figure 8-8, the number of airports in each group is listed under the appropriate data point.

Additionally, runway incursion rates before and after activation were examined for each of the airports where installed. Figure 6-7 shows the incursion rate at Providence (PVD) where RGLs were activated in 2000. Sixty-three percent of the airports showed a decrease in the incursion rate after RGL activation. See [15] for detailed incursion rate plots for each airport.

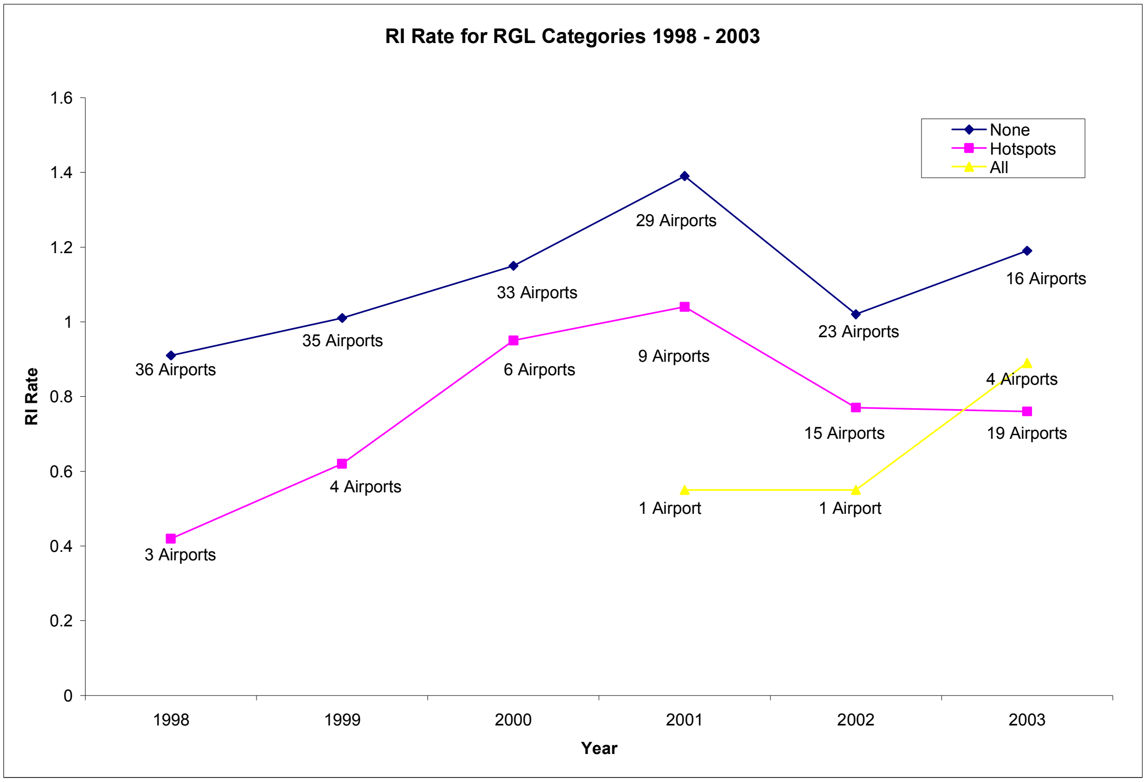


Figure 6-6. Runway Incursion Rate for RGL Categories

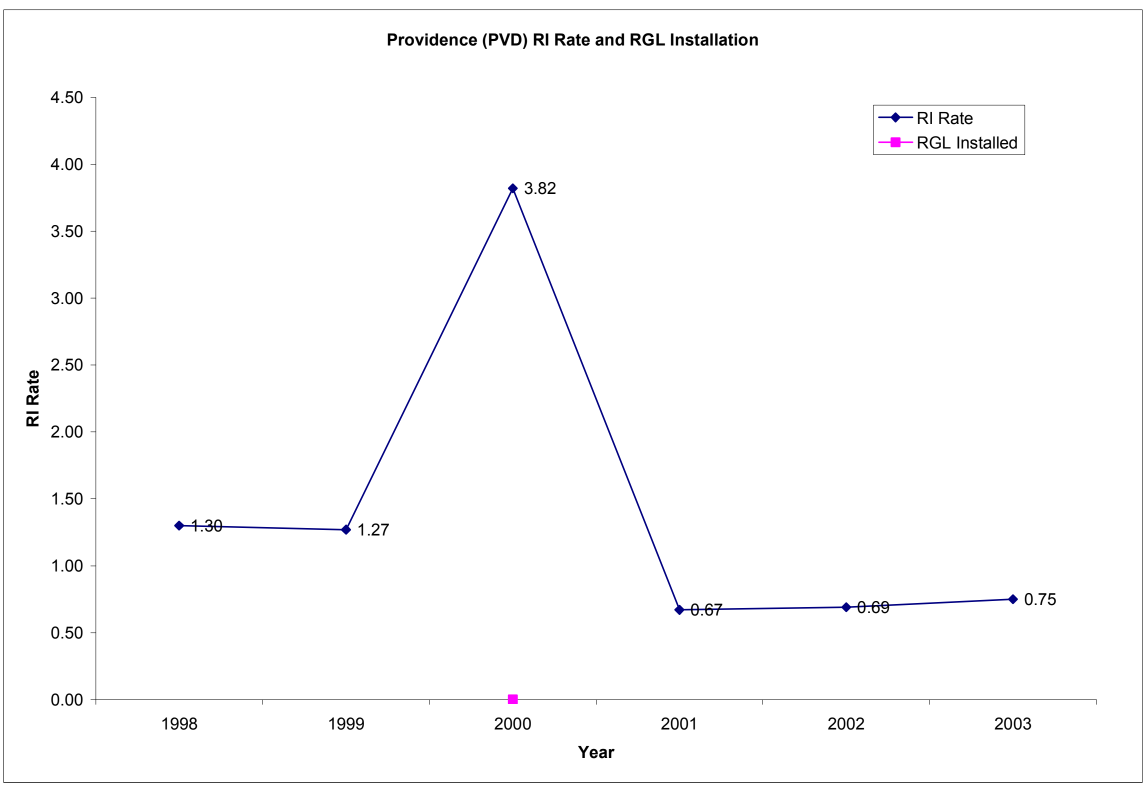


Figure 6-7. Runway Incursion Rate at PVD 1998 - 2003

Some airports did not see a noticeable drop in incursion rates after activation of RGLs. An example of this set of airports is Figure 6-8, which displays the incursion rate at Los Angeles International Airport (LAX)), where RGLs were activated in 2002.

As mentioned before, the incursion severities were also examined. Figure 6-9 shows the severity of runway incursions at LAX. While the total number of incursions before and after RGL activation was similar, the number of severe incursions (A & B) declined after RGL activation. The percentage of airports that exhibited a decline in the number of severe runway incursions after RGL activation was 88 percent. See [15] for detailed runway incursion severity charts for each airport examined.

The assessment of other airports that have RGLs supports the idea that RGLs reduce the severity of runway incursions and thereby increase surface safety. The EAL team will continue to perform similar analyses at VGT as data becomes available. It is expected that the full installation of RGLs across the entire airport at VGT, and the use of these lights in all weather conditions will prove even more effective than previous installations.

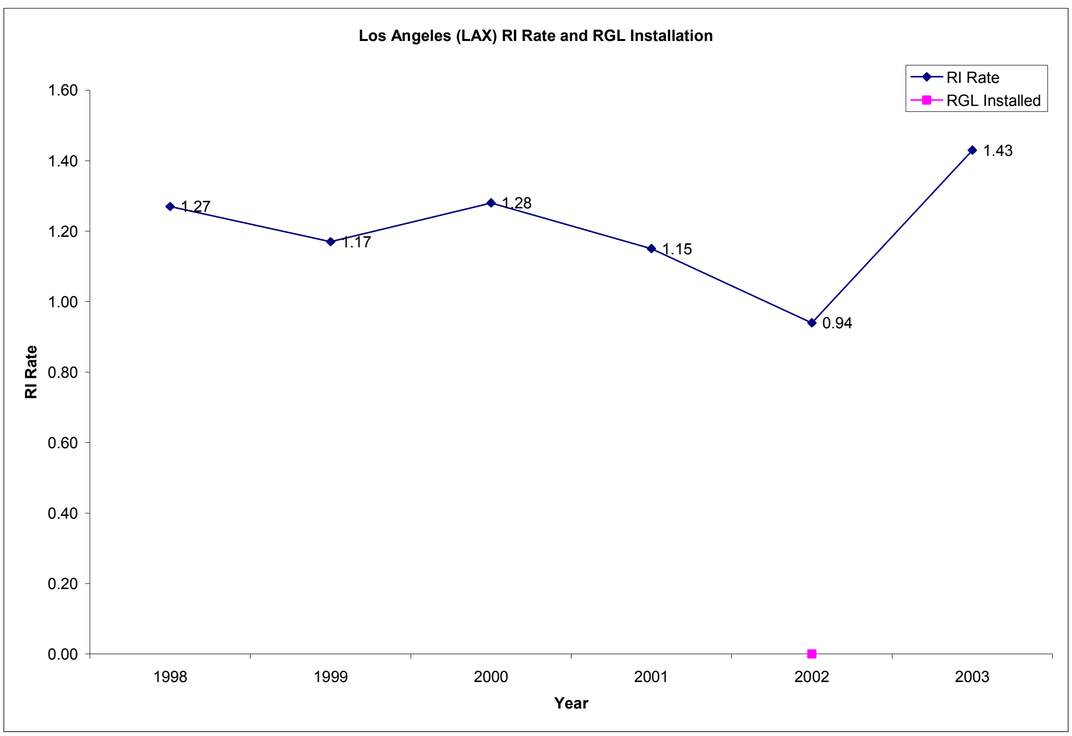


Figure 6-8. Runway Incursion Rate at LAX 1998-2003

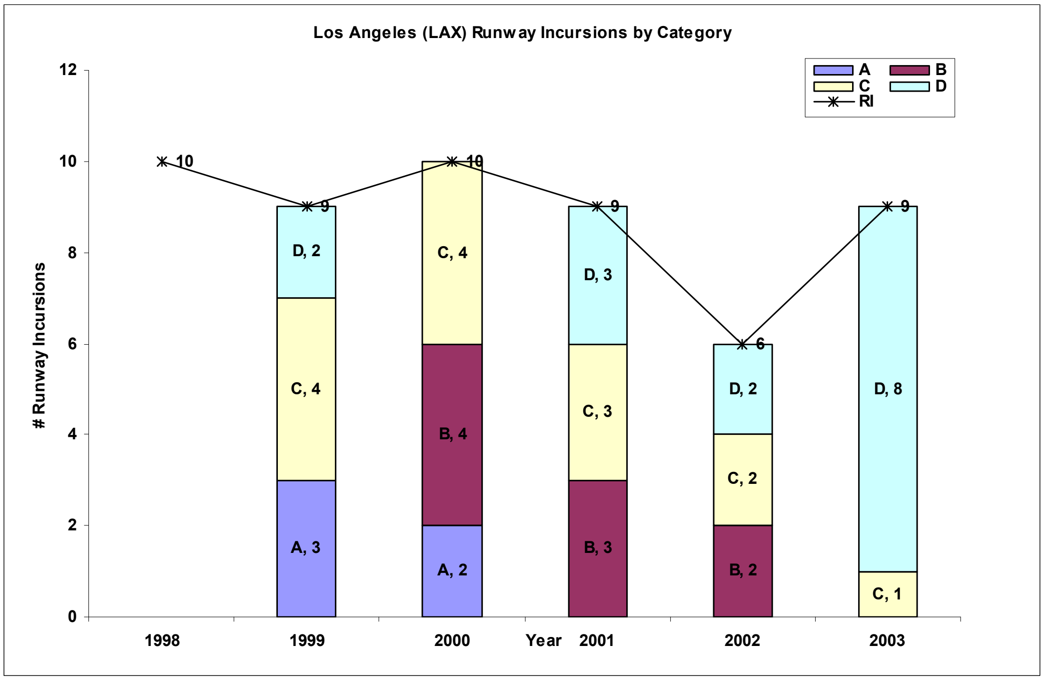


Figure 6-9. Runway Incursion Severity at LAX 1998-2003

7.0 MEM

7.1 System Description and History

The Future Surveillance Surface Applications Group assisted Federal Express (FedEx) and Northwest Airlines (NWA) in obtaining data for surface surveillance systems for use by ramp controllers and others within these airlines to whom this information is useful. The input for this system currently comes from prototype ASDE-X multilateration. Both FedEx and NWA have tested a variety of commercially available surface management tools to display and process the current data and are actively trying to determine the value of this new information. The multilateration data is also being used as the primary input for the Surface Management System (SMS). SMS is a decision support tool for the ATC tower that will use surface surveillance information to provide accurate arrival/departure demand, predicted pushback times, and runway utilization. Technology Development transferred responsibility for data sharing to the FAA's ATO Terminal Services Division during FY2004.

7.2 Metrics Activities

FedEx has been using surface surveillance data since April 2003 to enhance surface awareness for controllers in the ramp tower and dispatchers in the systems operations center. ATO Technology Development approached FedEx in November 2003 with the idea of measuring user benefits of shared surface surveillance. Even though Technology Development transferred responsibility of the surface effort at MEM to ATO Terminal Services, we thought benefit results at this location would be beneficial to our other surface efforts. Also, Terminal Services expressed interest in using our results in their business case for ASDE-X multilateration data sharing.

7.3 Results

Our usual first step at each site is to develop a benefits flow to describe the impacts of the new tool we hope to study. At MEM, Raytheon [21] and NASA [22] had already done detailed benefits descriptions in support of the NASA SMS effort. While the descriptions are not in exactly the same format as ours, they are sufficient to describe the impacts.

7.3.1 Summary of Previous Results

As we began to examine benefits at MEM, an opportunity arose to perform a quick study of taxi times. FedEx lost data tags for their surface surveillance system due to a hardware conflict during the FAA installation of the Standard Terminal Automation Replacement System (STARS) on October 27, 2003. Future Surveillance resolved the issue and data tags reappeared on December 17, 2003. In *Performance Metrics Results to Date April 2004* [2], we used this unexpected loss of surveillance to gauge the operational impact of surface data to FedEx.

We found that when the airport is in a North Flow operation (61% of the time), the average taxi-out time is 1.3 minutes less with surveillance during VA conditions and 4.3 minutes less with surveillance during IA conditions. For the same case, the percentage of taxi-out times that are greater than 40 minutes decreases by at least half. We found no significant change in the taxi-out time during South Flow.

In *Performance Metrics Results to Date October 2004* [1], we repeated the analysis comparing a year of post-implementation data to a year of data before implementation. For North Flow, the mean taxi time decreased by about 0.7 minutes in both VA and IA conditions. For South Flow, the taxi-out time decreased by approximately 0.3 minutes in VA conditions, and there was an insignificant change in IA conditions.

Another way to examine surface efficiency is in relation to surface queue length. We defined the queue for an aircraft to be the number of takeoffs between an aircraft's pushback and takeoff. This definition of queue length also allows examination of airport departure rates. Using the taxi time and queue length values for each flight, we examined the average departure rates for the different data sets. Using the outage event data, we found the departure rate over all the FedEx aircraft was, on average, 2.8 aircraft/hour greater during the surveillance period. Using the year of pre and post implementation data, we found the average over departure rate over all queue lengths was 3.0 aircraft/hour greater with surveillance.

7.3.2 New Departure Capacity Plateau Analysis

After presenting the average departure rate results mentioned in the **7.3.1**, it was suggested we examine the maximum departure rate, or departure capacity, for different runway configurations and weather conditions. The data sets used in the below analyses are described in detail in *Performance Metrics Results to Date October 2004* [1].

Figure 7-1 displays the mean hourly departure rate versus queue length during the surveillance and outage periods for each of the four airport configuration-weather condition pairs.

For the North Flow graphs in Figure 7-1, the average departure rate in the surveillance period is higher for each value of surface demand (queue length). The difference is especially noticeable in North Flow, IA conditions.

At high demands, both the surveillance and outage curves flatten to approximately 80 aircraft/hour. The departure rate plateau for the surveillance period is greater than that for the outage data by several aircraft per hour for the North Flow cases, and not much different for the South Flow cases.

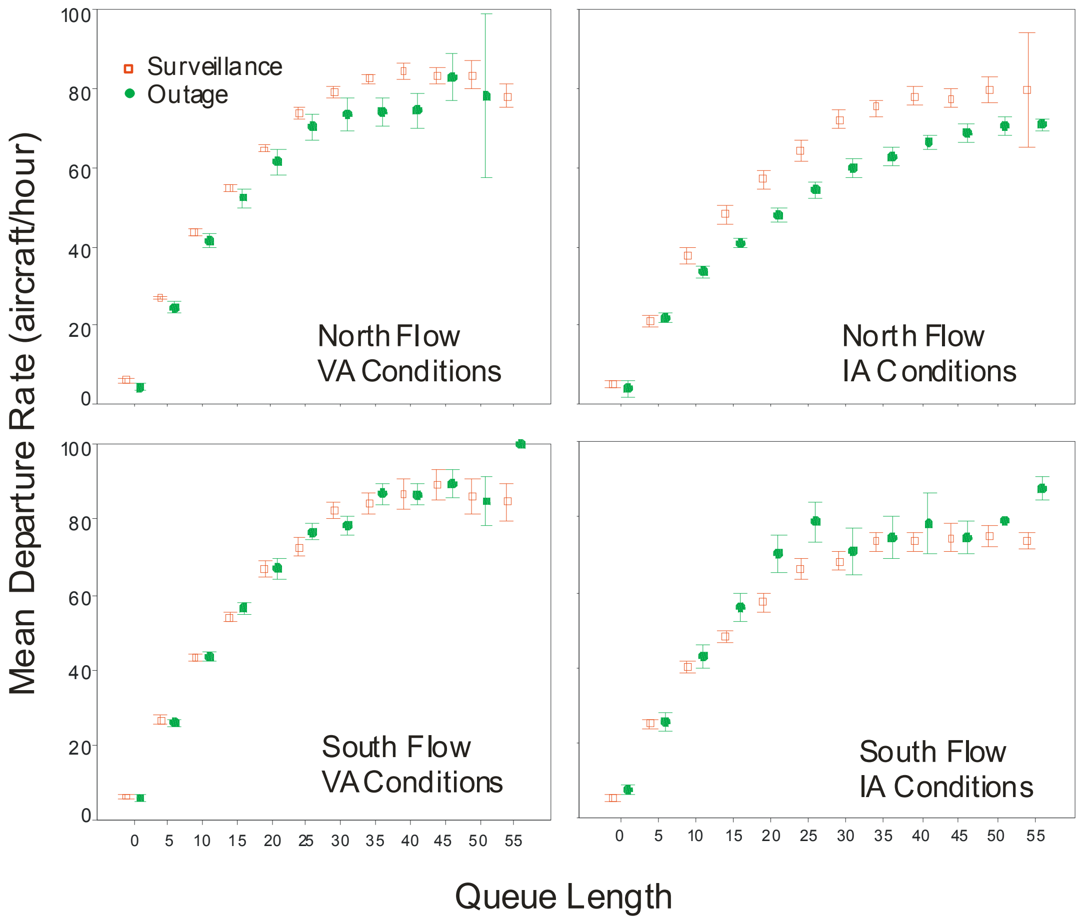


Figure 7-1. Departure rate vs. queue length, surveillance outage data

There are several methods that can be used to estimate a value for the departure rate plateau. We decided to examine the mean value of the departure rate for all flights that have queue lengths of 35 or greater. An independent samples *t*-test was performed to determine if the difference in the means was significant. Table 7-1 presents the departure rate plateau mean values, the difference in the means, and the p-value results of the *t*-test. A p-value of .050 or greater is **not** significant at the 95 percent level. Note that the difference in the means is significant for the North Flow cases and not significant for the South Flow cases.

Table 7-1. Departure rate plateau means and differences, surveillance outage data

Airport Configuration	Weather Conditions	Surveillance (aircraft/hour)	Outage (aircraft/hour)	Difference (aircraft/hour)	*t*-test p-value
North	VA	83.0	75.6	7.5	.000
	IA	77.1	66.6	10.4	.000
South	VA	85.4	87.1	-1.7	.190
	IA	73.8	76.0	-2.1	.237

As a further confirmation of the surface surveillance benefit at MEM, we decided to compare data after implementation to that before implementation (as opposed to during the outage). Since FedEx reports that they began to use surface surveillance operationally in late March 2003, we chose a baseline period of April 1, 2002 to March 31, 2003, and the post-implementation period as April 1, 2003 through March 31, 2004. We removed November and December flights from both data sets to account for the outage in the post-implementation period.

We also repeat the queuing and departure rate analysis for the pre- post-implementation data sets. Figure 7-2 displays the mean departure rate versus queue length during the pre- and post-implementation periods for each of the four airport configuration-weather condition pairs. Table 7-2 presents the departure rate plateau mean values, the difference in the means, and the p-value results of the *t*-test.

For the North Flow graphs in Figure 7-2, the average departure rate in the after period is higher than the before period for most of the high values of surface demand (queue length greater than 30).

As with the surveillance outage data, both the pre- and post-implementation curves flatten to approximately 80 aircraft/hour. The departure rate plateau for the after period is greater than that for the before data by between 5 and 7 aircraft per hour for the North Flow cases, and not much different for the South Flow cases. An independent samples *t*-test was performed to determine if the difference in the means was significant. Note that the difference in the means is significant at the 95 percent level for the North Flow cases and not significant for the South Flow cases.

We believe the departure rate results represent an effective departure capacity increase caused by demand management using shared surface surveillance. The magnitude of the departure capacity increase was approximately 5-10 aircraft/hour during North Flow operations. No significant trends were seen in South Flow operations. This change in departure capacity should be useful for future benefits estimation.

These results reveal the significant benefits of providing surface surveillance for the airlines. Surface surveillance tools allow FedEx to precondition the surface flows so as to assist FAA ground controllers in optimizing runway throughput. We expect that as similar tools for FAA facilities become available, the benefits may increase because of increased collaboration and control. While the nighttime air cargo operation of FedEx at MEM is a somewhat specialized case as compared to general airline operations, we believe the benefit mechanisms mentioned here should still be valid for most airlines operating at busy airports.

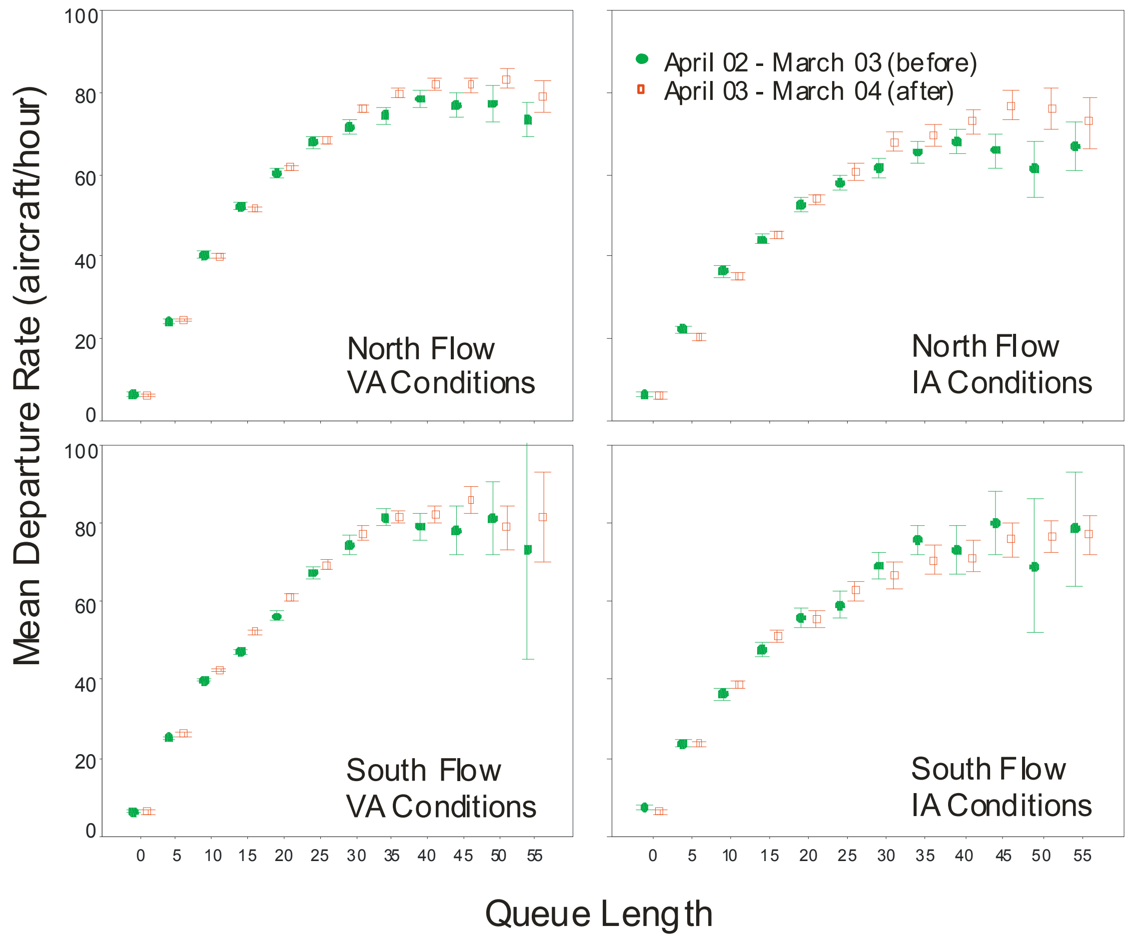


Figure 7-2. Departure rate vs. queue length, pre/post implementation data

Table 7-2. Departure rate plateau means and differences, pre/post implementation data

Runway Flow	Weather Conditions	After (aircraft/hour)	Before (aircraft/hour)	Difference (aircraft/hour)	*t*-test p-value
North	VA	81.1	76.1	5.1	.000
	IA	72.8	65.9	6.9	.000
South	VA	82.2	80.3	1.9	.109
	IA	72.4	75.3	-2.9	.100

8.0 DTW

8.1 System Description and History

The Airport Target Identification System (ATIDS) is a prototype multilateration system that provides accurate position information of transponder-equipped aircraft operating on the airport surface. A government/industry partnership between the FAA, NASA, Sensis Corporation, and the DTW airport authority installed ATIDS as a research and development project in 1999.

The DTW ATIDS consists of nine remote unit sensors providing surface surveillance coverage. In February 2002, Technology Development installed communications and computer equipment, including three displays within the Northwest Airlines (NWA) ramp tower and displays at the NWA System Operations Center (SOC) in Minneapolis, MN. The purpose of this effort was to probe the benefits of distributing real-time, filtered surveillance data to an airport user. The system provides NWA with aircraft position and flight call sign information. The FAA also prepared a data sharing Memorandum of Agreement with NWA that formally launched the demonstration. During the subsequent one-year period, anecdotal evidence indicated that the sharing of surface surveillance data had a positive impact on efficiency and safety. To further explore these benefits, the FAA established a metrics working group in February 2003.

8.2 Metrics Activities

The working group collected metrics data and other pertinent information to evaluate efficiency and safety. The group included members from the FAA, NWA, NASA, NATCA, DTW ATC, the Volpe National Transportation Systems Center, and Sensis Inc.

In April 2003, at a meeting facilitated by Volpe, the group discussed the current operational impact of ATIDS. Members explained the direct impact of each capability and discussed the benefits that arise from these impacts. Subsequently, we developed a "benefits flow" (Figure 8-1) as described in section **1.3**.

8.3 Results

In *Performance Metrics Results to Date October 2003* [3], we presented the benefits flow and attempted to quantify the impacts where possible. In *Performance Metrics Results to Date October 2004* [1], we presented a new description of how ATIDS helped NWA permanently transform deicing operations. The new description included a list of long-term changes. Below we summarize the previous results.

8.3.1 Summary of Previous Results

The summaries below are organized by the benefits flow outcomes seen in Figure 8-1.

• More efficient movement in the ramp area – NWA ramp controllers are responsible for movement in a large area at DTW. They use ATIDS as their primary display in the ramp tower. NWA estimates that these activities currently save 2464 hours of taxi time per year.

• More efficient handling during irregular operations – Irregular operations include times of severe snow and ice, fog, and heavy crosswinds when operations are severely hampered. NWA recently changed its deice operations due to analyses based on post-event ATIDS data. We presented an estimation of the effectiveness of this systematic change in a later benefit. Above and beyond the systematic changes, the NWA SOC documented a real-time use of the ATIDS display that prevented 20-24 cancellations during one particularly bad deicing event in April 2003. The ramp control estimates that ATIDS saves approximately 32 hours of taxi time a year during heavy fog.

• Less likelihood of ramp incidents – While the occurrence of ramp incidents at DTW is quite small, we described how the ATIDS display helps NWA ramp control insure safe operations.

• More efficient maintenance and emergency response (ramp) – NWA ramp control uses ATIDS to help locate and expedite maintenance or emergency flights during low visibility. We presented an example where they used ATIDS to avoid a 5-minute delay on a medical emergency.

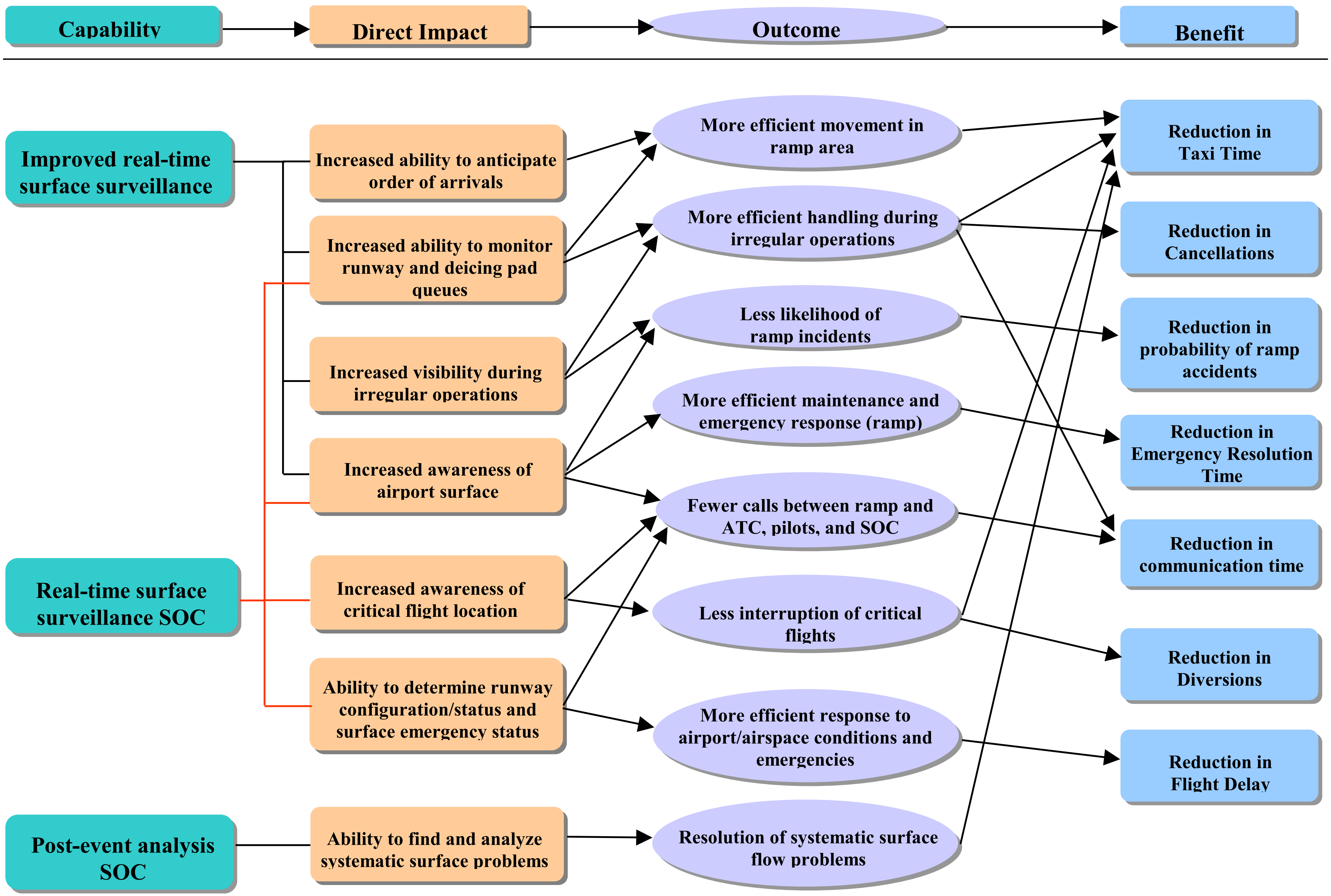
• Fewer calls between ramp, SOC, pilots, and Air Traffic Control (ATC) – Because the ATIDS display provides a means of increased situational awareness, the NWA SOC has been able to reduce calls to the DTW ATC regarding flight location by 75%. Added surveillance on the surface allows NWA ramp control to decrease the number of calls to pilots by 27%.

• Less interruption of critical flights – The NWA SOC uses the tool to gather information on flights that are running close to a curfew or duty limit and propose solutions to ATC. We included some examples of this activity.

• More efficient response to airport/airspace conditions and emergencies – NWA dispatchers at the SOC use ATIDS on a daily basis to reroute flights being held on the ground due to congested en route traffic. We used examples to estimate a yearly savings of 89 hours of block time. The NWA SOC also uses the tool to obtain up-to-date information on potential emergencies at DTW. We included examples of this activity.

• Resolution of systematic surface flow problems – One of the most beneficial recent changes at DTW occurred because of post-event analyses of ATIDS data during a deicing event. We presented an example of how NWA completely changed their deicing procedures because of evidence gathered using ATIDS. The NWA SOC estimated that 432-720 hours of flight delay a year will be saved through ATIDS monitoring after changes made in the procedures. We also described how NWA is using ATIDS to examine other procedural issues.

Figure 8-1. DTW Data Sharing on Surface Benefits Flow



9.0 GULF OF MEXICO

9.1 System Description and History

The Future Surveillance En route and Oceanic Application Group focuses on developing ADS-B applications for use in areas with no radar coverage, such as the Gulf of Mexico.

In March of 2003, the En route and Oceanic Group began a concerted effort to identify future benefits for ADS-B in the Gulf of Mexico. The current effort in the gulf involves estimating future benefits, not measuring current benefits of any deployed tool. However, cooperation of the cost/benefit and metrics teams is essential to provide a consistent story throughout the life cycle of a project. To this end, the ATO Technology Development Metrics Team is assisting in the benefits identification process and will be active in gathering and analyzing baseline data for this effort.

9.2 Metrics Activities

In the spring of 2003, Technology Development started to develop benefits flows (much like those described at other sites) in coordination with Continental Airlines, Houston ARTCC, NATCA, and representatives of the helicopter industry.

In the *Performance Metrics Results to Date April 2004* [2], we presented the current Gulf of Mexico benefits projections. The metrics team will assist in further projections as requested.

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11.0 ACRONYMS

ACARS	Addressing, Communications, and Reporting System
ADS-B	Automatic Dependent Surveillance – Broadcast
AND-500	Past FAA routing symbol for office now within ATO Technology Development
ATIDS	Airport Target Identification System
AOC	Airline Operations Center
AOPA	Aircraft Owners and Pilots Association
AOZ-40	FAA Free Flight Program Office
ARINC	Aeronautical Radio, Inc.
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Tracking System
ASDE-3	Airport Surface Detection Equipment radar surveillance
ASDE-X	Airport Surface Detection Equipment Model X
ASPM	Aviation System Performance Metrics
ASR	Airport Surveillance Radar
ATA	Air Transport Association
ATC	Air Traffic Control
ATO	Air Traffic Organization
B-757	Boeing 757
B-767	Boeing 767
CAASD	Center for Advanced Aviation System Development
CBA	Cost Benefit Analysis
CDA	Continuous Descent Approach
CDTI	Cockpit Display of Traffic Information
CEFR	CDTI-Enhanced Flight Rules
CFIT	Controlled Flight into Terrain
CNAC	Center for Naval Analysis Corporation
CRABS	Comprehensive Real-time Analysis of Broadcast Systems
CTAS	Center TRACON Automation System
DFW	Dallas-Fort Worth Airport
DOT	Department of Transportation
DPS	Department of Public Safety
DTW	Detroit Wayne County Airport
EAL	Enhanced Airport Lighting
EFC	Expected Further Clearance
EOC	Emergency Operations Center
ERAU	Embry-Riddle Aeronautical University
ETA	Estimated Time of Arrival
ETMS	Enhanced Traffic Management System
EVA	Enhanced Visual Approach

FAA	Federal Aviation Administration
FBO	Fixed Base Operator
FedEx	Federal Express, Inc.
FFP	Free Flight Program
FIS-B	Flight Information Service-Broadcast
GEMS	Global Engineering Management Services, Inc.
GMT	Greenwich Mean Time
GOM	Gulf of Mexico
GPS	Global Positioning System
HAME	Host Aircraft Management Executive
HSAC	Helicopter Safety Advisory Conference
IA	Instrument Approaches
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IPA	International Pilots Association
JHUAPL	Johns Hopkins University Applied Physics Laboratory
LAX	Los Angeles International Airport
MAP	Monitor Alert Parameter
MEM	Memphis International Airport
MFD	Multi-functional Display
MLAT	Multilateration
MOU	Memorandum of Understanding
MVA	Marginal Visual Approaches
MVMC	Marginal Visual Meteorological Conditions
N	Neither Agree Nor Disagree
NA	Not Applicable
NAS	National Airspace System
NASDAC	National Aviation Safety Data Analysis Center
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Control Association
NCDC	National Climatic Data Center
NMAC	Near Mid-Air Collision
Nmi	Nautical mile(s)
NORAD	North American Aerospace Defense Command
NTX	NASA North Texas Station
NWA	Northwest Airlines
OEP	Operational Evolution Plan
OOOI	Out Off On In
PD	Pilot Deviation

PVD	Providence International Airport
RAA	Regional Airport Authority
RCC	Ramp Control Center
REL	Runway Entrance Lights
RGL	Runway Guard Lights
RI	Runway Incursion
RIRP	Runway Incursion Reduction Program
RSAT	Runway Safety Action Team
RTCA	RTCA, Inc.
RVR	Runway Visual Range
RWSL	Runway Status Lights
SA	Strongly Agree
SAN	San Diego International Airport
SD	Strongly Disagree
SDF	Louisville International Airport – Standiford Field
SF-21	Safe Flight 21
SMA	Surface Movement Advisor
SMGCS	Surface Movement and Guidance Control System
SMS	Surface Management System
SOC	System Operations Center
STARS	Standard Terminal Automation Replacement System
SUA	Special Use Airspace
SWA	Somewhat Agree
SWD	Somewhat Disagree
TCAS	Traffic Alert and Collision Avoidance System
TESIS	Test and Evaluation Surveillance Information System
THL	Takeoff Hold Lights
TIS-B	Traffic Information Service-Broadcast
TRACON	Terminal Radar Approach Control Facility
UPS	United Parcel Service
VA	Visual Approaches
VFR	Visual Flight Rules
VGT	North Las Vegas Airport
VMC	Visual Meteorological Conditions